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Energy Scenarios and Implementation of New Technologies for Spain

by

J. O. Costa, V. Gil Sordo, M. Blasco, A. Jara

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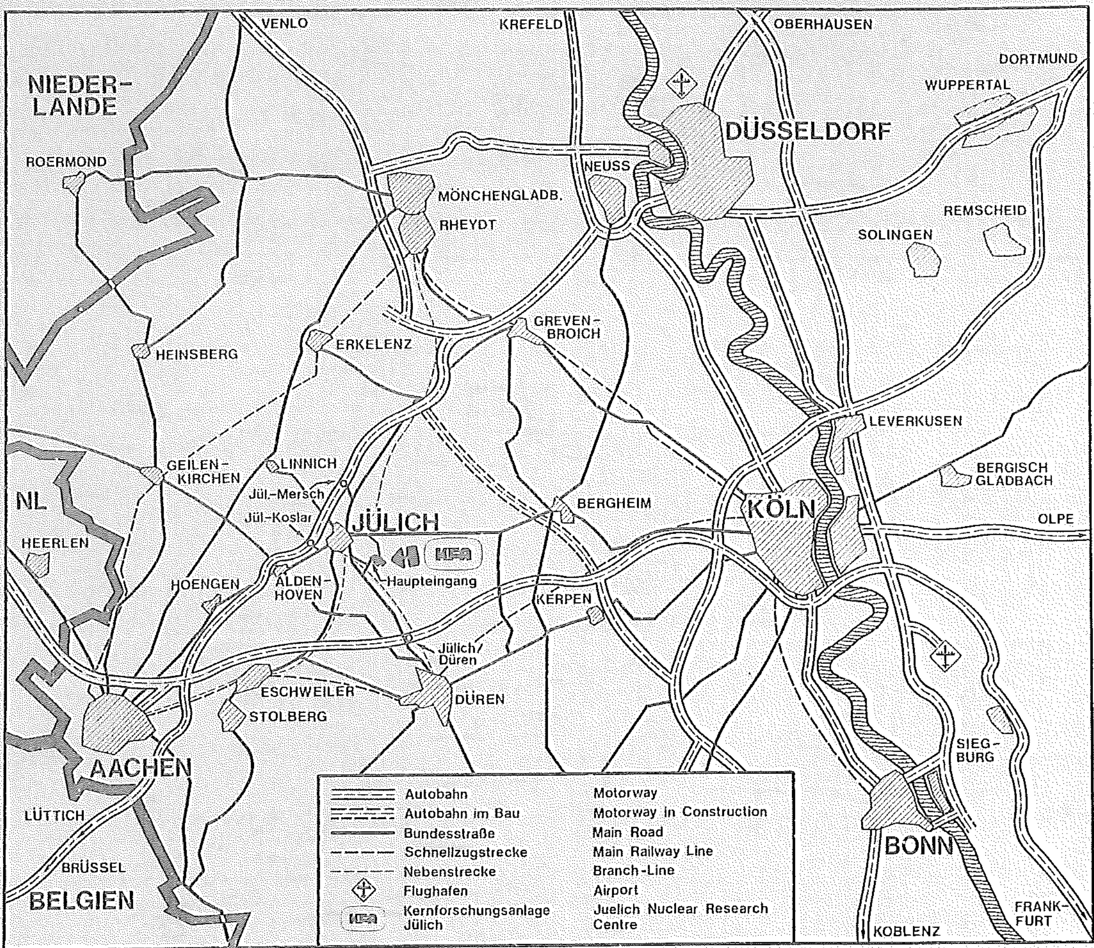

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Report of the IEA Energy Systems Analysis Project
at
Brookhaven National Laboratory Upton, NY 11973, USA
and
Kernforschungsanlage Jülich, D-5170 Jülich, Germany

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Approximately fifty people participated in the second Phase of the IEA Systems Analysis Project. Some of them were members of the staff, either at the Kernforschungsanlage Jülich (FRG) or at the Brookhaven National Laboratory (USA), and the remainder were as country representatives.

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1. INTRODUCTION

1.1 History of the Project

The International Energy Agency is an autonomous body established in November 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD). Nineteen of the OECD's twenty-four member countries participate in the IEA*, and the Commission of the European Communities takes part by special arrangement.

The IEA has been established to implement the International Energy Program (IEP) adopted by the participating countries on 18th November, 1974, the basic objectives of which being: (i) to take measures to meet oil supply emergencies; (ii) to reduce dependence on imported oil by undertaking long-term cooperative efforts on conservation of energy, on accelerated development of alternative sources of energy and on research, development and demonstration in the energy field; (iii) to promote cooperative relations with oil-producing countries and other oil-consuming countries, including those of the developing world, through a purposeful dialogue. Within the context of the Agency's long term cooperation programme, the participating countries have agreed to carry out national programmes of energy research, development and demonstration, and as may be agreed between some or all of them, to undertake cooperative activities including jointly financed programmes and projects in energy research and development.

In further support of this cooperation, the participating countries have agreed to develop and implement an appropriate strategy for research and development. This strategy will be closely linked to and coordinated with the other parts of the Agency's long term

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*IEA member countries: Austria, Belgium, Canada, Denmark, Germany, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.
(Note: in 1979 the IEA membership was increased to twenty countries with the admission of Australia.)

programme. It will identify major new energy sources and conservation possibilities; their potential energy contribution and probable time scale of commercial implementation, and define technological options; and will identify possible new areas of fruitful cooperation.[a)]

In April 1976, the Committee on Energy Research and Development (CRD)[b)], which is responsible for the IEA's cooperative RD&D efforts, established a systems analysis project whose primary objective was to evaluate new energy technologies and thereby assist in the formulation of an IEA RD&D strategy. A Steering Group[c)], consisting of delegates from the participating IEA member countries[d)], was organised to set objectives and guide the work plan of the project. Phase I of this project finished in March 1977, and the results of the work were documented.[e)]

Phase II of the project, which is the subject of this report, began on April 1st, 1977 and ended in March, 1980. During this phase of the work, a computer model, MARKAL, was developed which allowed an evaluation of the potential impact of new technologies in competition with each other and with existing technologies under conditions related to various policy and physical constraints (scenarios). MARKAL is a flexible multi-period linear programming model which is capable of describing the time evolution of widely diverse energy systems under a variety of constraints and objective functions.

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a) Quoted from: International Energy Agency, Energy Research, Development and Demonstration, Programme of the IEA, May 1977, OECD, 2, rue André-Pascal, 75775 Paris, Cedex 16, France.

b) In 1976 Dr. W. Schmidt-Kuster was Chairman of CRD.

c) Dr. Roger LeGassie served as Chairman of the Steering Group from 1976 until November 1978, when he was succeeded by Dr. Richard H. Williamson.

d) Participants included Austria, Belgium, Canada, Denmark, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom, United States and the CEC.

e) IEA Energy Systems Analysis Project, An Initial Multi-National Study of Future Energy Systems, and Impacts of Some Evolving Technologies, prepared jointly by the project staffs at Brookhaven National Laboratory and Kernforschungsanlage Jülich, BNL-50641/Jül-1406, March 25th, 1977.

By the end of 1979, fifteen countries had completed analyses of 9 to 16 scenarios using the MARKAL model. These results are summarised in the Phase II final reports of the individual countries. This is one such report.

It should be noted that there are two versions of MARKAL, the BNL and the KFA version. These were necessary because of the different computer hardware and software systems at the two laboratories. Users' guides for each version have been published[f) g)]. Although the two versions differ in computer programming detail, they have the same structure and, in principle, perform identical calculations. An effort will be made in the future to reconcile the minor differences which remain and to standardise the input formats and the output reports.

A major part of the project effort has been devoted to the quantitative descriptions of existing and new technologies. This data serves as input to the model. In particular, the new technologies in the supply sector have been subjected to extensive detailed review by the project staff and experts from industry and government institutions of the participating countries. For many technologies a standard set of reference values which characterise the technology have been adopted. Individual countries have modified the reference values in order to account for local conditions, e.g. labour costs and other economic factors, geographical factors, and specific national standard for environmental protection and public safety. The reference data and the data used by individual countries has been documented.

The development of MARKAL, the technology characterisations, and the analytical studies are the result of an international collaboration which has involved approximately 50 people from the 16 participating countries and the CEC.

[f)] H. Abilock and L. Fishbone, Users' Guide for MARKAL (BNL Version), BNL December 31st, 1979

[g)] G. Giesen, H.A. Hymmen, K. Leimkühler, Users' Guide for MARKAL (KFA Version), May 1980

1.2 Objectives of the Project

The main aim of the project is to develop an overall IEA Research, Development and Demonstration (RD&D) strategy. The organisation of the project is shown in Figure 1.

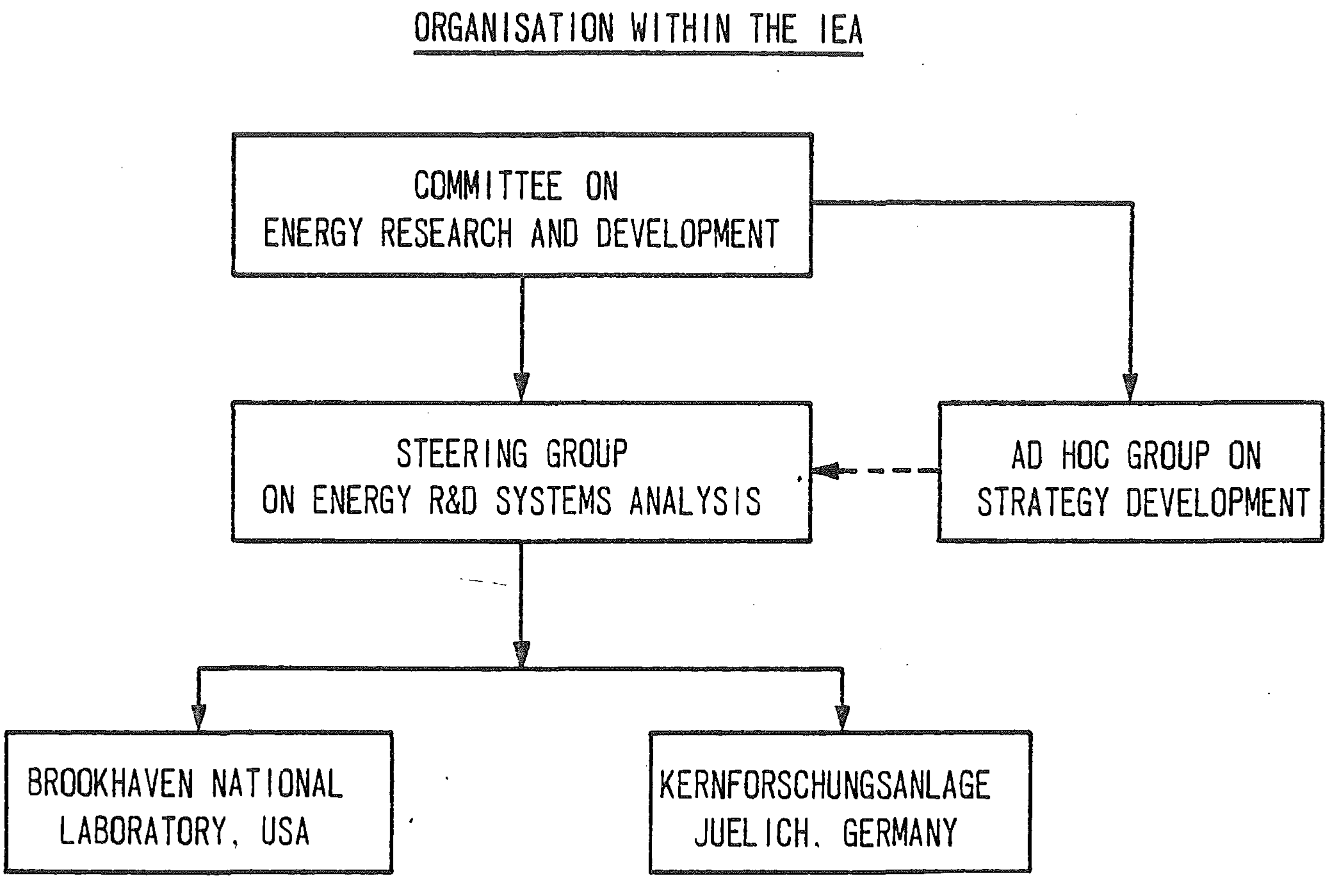

Figure 1: Organisation of the Project

The main purposes of the IEA RD&D strategy are:

- To establish estimates and targets for the potential contribution of individual new and improved technologies, taking into account their performances, costs and energy contribution.

- To establish a base for an effective linkage between national RD&D strategies, and

- To identify non-technology policy issues which could hamper the introduction of promising technological options.

The main purpose of this report is to provide the IEA Steering Group and the Spanish authorities with information about the Spanish energy system and the potential role of new technologies within it.

2. THE MARKAL MODEL

2.1 Methodology

The scenarios presented in this report have been computed with the KFA version of the time-dependent linear programming model MARKAL. Since the model was developed mainly to evaluate the possible impacts of new technologies on national systems, it is flexible in structure and it is therefore possible to apply the model to a large variety of scenarios or cases.

MARKAL determines the optimum structure of the energy system over the whole time span considered, dependent on a given objective function (generally the total discounted cycle in cost) and exogenously specified constraints. The latter includes availability of resources, costs and energy demands.

It is only possible to obtain feasible solutions if all end-use demands specified by the user can be satisfied for every time period. The duration and number of time periods are specified by the user, although in the IEA Systems Analysis Project nine five-year periods were considered by all participating countries. The time periods are centred at 1980, 1985, ..., 2020, covering a time span of 45 years. If an optimal solution is obtained, its structure depends on the objective function used, the technological and economic data supplied by the user and the constraints considered. These items will be explained in more detail in the following parts of this report.

The size of the Spanish model is at present approximately 1700 rows and 3700 variables. The flexibilitiy of the model structure allows the user to alter readily the structure and aggregation of the demand sectors and also the number and type of technologies.

The development time for the KFA version of MARKAL has been approximately 1,5 years, and the corresponding documentation has already been published (see footnote g) on page 3).

2.2 The MARKAL Energy System

The model simulates the flow of energy from the primary energy carriers, through transformation systems, to the demand devices which satisfy the specified demands.

The energy system which MARKAL represents is shown in Figure 2.

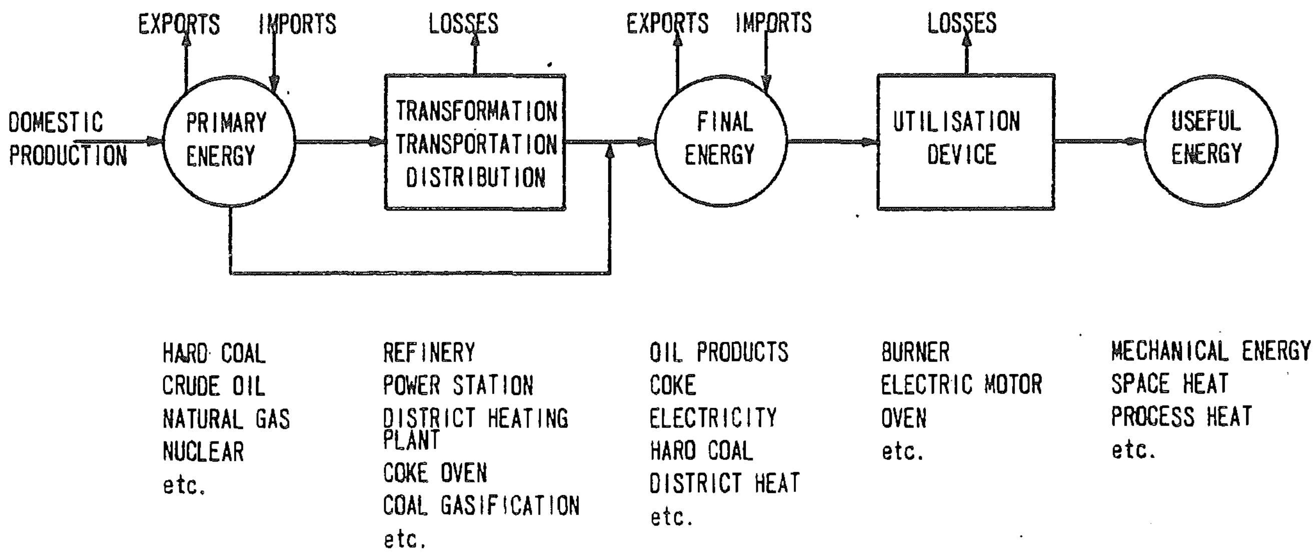

Figure 2: MARKAL Energy System

The circles show the different categories of energy considered: primary energy, final energy and useful energy. Only final and primary energy can be imported or exported. Primary energy is available from either domestic production or imports. The changes from one category to another are shown by rectangles; the left one shows the conversion from primary to final energy and the right one from final to useful energy. The corresponding losses resulting from both transformations are also shown. There are also transport and distribution losses which must be considered. For the conversion from primary to final energy, the conversion systems are technologies such as electric power plants, district heating plants, coal gasification plants, coke ovens, etc. Burners, electric motors, ovens, etc. convert final to useful energy. The corresponding technical, economic and environmental data (1) must be specified for each technology. The possibilities for imports and exports of primary energy are also shown.

The MARKAL codes used are listed and explained in Table 1.

2.3 Examples of Inputs and Outputs

Figure 3 shows the model inputs and outputs. It is necessary to specify the following inputs:

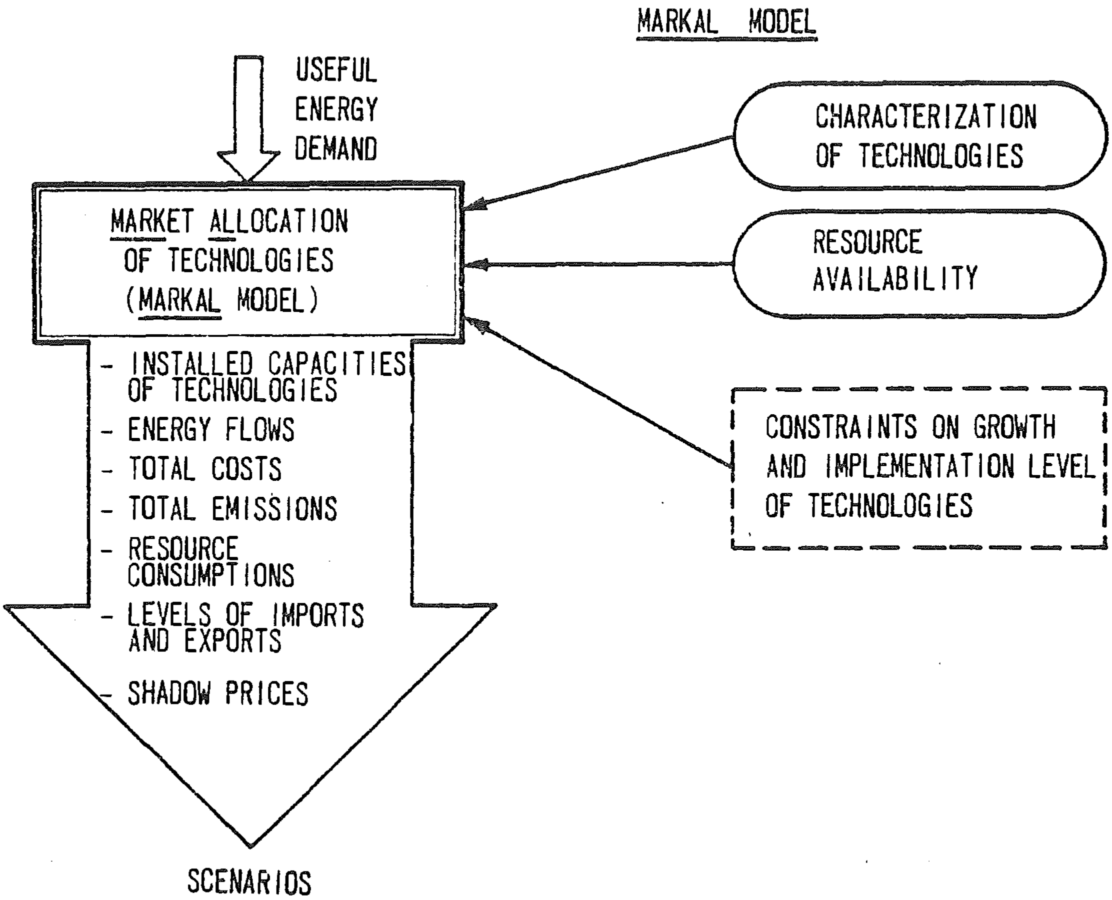

Figure 3: The MARKAL Model

(1) The work plan has not allowed for the inclusion of environmental data in the model.

TABLE 1. MARKAL CODES

DEMAND DEVICES

I1Y	IRON STEEL PROD NON SUBST MIX
I17	IRON STEEL PROD GAS BURNER
I16	IRON STEEL PROD DSH BURNER
IX2	OTHER INDUSTRIAL HCO BURNERS
IX3	OTHER INDUSTRIAL DSL BURNERS
IX6	OTHER INDUSTRIAL DSH BURNERS
IX7	OTHER INDUSTRIAL GAS BURNERS
IX1	OTHER INDUSTRIAL ELC MIX
NYY	NON ENERGY USE MIX
R20	SP HT SFDW ELC STORAGE
R21	SP HT SFDW ELC UNRESTRICTED
R23	SP HT SFDW OIL
R27	SP HT SFDW GAS
R2A	SP HT SFDW ELC HEAT PUMP
R2B	SP HT SFDW GAS HEAT PUMP
R2D	SP HT SFDW SOLAR
R2G	SP HT SFDW AND MW BACK UP OIL
R2H	SP HT SFDW AND WW BACK UP GAS
R2Y	SP HT SFDW EXISTING MIX
R51	WW ALL ELECTRIC
R53	WW ALL OIL
R57	WW ALL GAS
R5D	WW ALL SOLAR
R5G	WW BACK UP OIL
R5H	WW BACK UP GAS
R5I	WW ALL OIL AND ELC
R5K	WW ALL GAS AND ELC
R5Y	WW ALL EXIST MIX
RDY	RES AND COMM OTHER USE
RT0	SP HT MFDW AND COMM ELC SOTORAGE
RT1	SP HT MFDW AND COMM ELC UNRESTRICTED
RT3	SP HT MFDW AND COMM OIL
RT7	SP HT MFDW AND COMM GAS
RTA	SP HT MFDW AND COMM ELECTRIC HEAT PUMP
RTB	SP HT MFDW AND COMM GAS HEAT PUMP
RTY	SP HT MFDW AND COMM EXIST MIX
T80	ROAD TRANSPORT ELECTRIC
T83	ROAD TRANSPORT DIESEL
T8F	ROAD TRANSPORT GASOLINE
TXY	RAIL AIR AND SHIP TRANSPORT MIX
T8V	ROAD TRANSPORT HYDROGEN

DEMAND SUBSECTORS

I1	IRON AND STEEL PRODUCTION
IX	OTHER INDUSTRIES(ALL EXCEPT I1)
NY	NON ENERGY USES
R2	RESIDENTIAL SPACE HEAT SFDW
R5	WATER HEAT ALL USERS
RD	LIGHTING AND APPLIANCES ALL USERS
RT	RESIDENCIAL MFDW AND COMMERCIAL SPACE HEAT
T8	ROAD TRANSPORT
TX	RAIL AIR AND SHIP TRANSPORT

TABLE 1. MARKAL CODES (Continued)

PROCESSES

S01	HARD COAL LURGI GASIFICATION
S02	HARD COAL TO MEDIUM BTU GAS
S04	HARD COAL TO METHANOL
S06	COKE OWEN
S21	DISTILLATION OF CRUDE OIL
S23	HYDROCRACKING OF HEAVY DISTILLATE OIL
S29	CATALYTIC CRACKING OF LIGHT DISTILLATE OIL
S40	ENR OF URN AND FABR OF LWR FUEL
S48	ENR AND FABR OF HTR FUEL FOR URN/THO CYCLE
S49	ENR AND FABR OF HTR FUEL FOR U35/THO CYCLE
S4A	FABR OF LMFBR FUEL FROM PLU AND UDP
S50	REPROCESSING OF LWR SPENT FUEL
S54	REPROCESSING OF LMFBR SPENT FUEL
S52	REPR OF HTR SPENT FUEL FROM URN/THO CYCLE
S53	REPR OF HTR SPENT FUEL FROM U35/THO CYCLE
S0A	HARD COAL NUCLEAR HYDROGASIFICATION
S0B	HARD COAL NUCLEAR STEAM GASIFICATION PLANT
S0F	HARD COAL LIQUEFACTION/HYDROGENATION
S0G	HARD COAL LIQUEFACTION FISCHER/TROPSCH
S11	BROWN COAL LURGI GASFICATION
S1A	BROWN COAL NUCLEAR HYDROGASFICATION
S71	VIRTUAL PROCESS,METHANOL INTO GASOLINE
S6A	VIRTUAL PROCESS,DSH TO POWER STATION FUEL
S6B	VIRTUAL PROCESS,DSL TO GAS TURBINE FUEL
S6C	VIRTUAL PROCESS,GAS TO GAS TURBINE FUEL
S6D	VIRTUAL PROCESS,HCO TO POWER STATION FUEL
S6E	VIRTUAL PROCESS,PFG TO POWER STATION FUEL
S6H	VIRTUAL PROCESS,HYDROGEN TO GAS
S6J	VIRTUAL PROCESS,HTR FUEL USE FOR URN/THO CYCLE
S6K	VIRTUAL PROCESS,HTR FUEL USE FOR U35/THO CYCLE
S80	HYDROGEN PRODUCTION FROM WATER ELECTROLYSIS

GENERATION OF ELECTRICITY

E01	HARD COAL POWER PLANT
E04	BROWN COAL POWER PLANT
E06	HARD COAL COMBINED CYCLE POWER PLANT
E0E	IN SITU COAL GASIFICATION FOR ELECTRICITY
E17	MIXED OIL AND GAS STEAM ELECTRIC
E18	MIXED OIL AND GAS TURBINE
E21	LWR NUCLEAR POWER PLANT
E25	HTR NUCLEAR POWER PLANT
E26	LMFBR NUCLEAR POWER PLANT
E28	FUSION ELECTRIC POWER PLANT
E31	CONVENTIONAL HYDROELECTRIC POWER PLANT
E35	WIND ELECTRIC POWER PLANT
E94	GAS FUEL CELL ELECTRIC
E4B	DISPERSED SOLAR PHOTOELECTRIC
E34	CENTRAL SOLAR THERMAL ELECTRIC

TABLE 1. MARKAL CODES (Continued)

ENERGY CARRIERS

MINHCO	DOMESTIC HARD COAL
MINBCO	DOMESTIC BROWN COAL
MINOIL	DOMESTIC CRUDE OIL
MINURN	MINING OF U308
MINGAS	DOMESTIC NATURAL GAS
IMPHCO	IMPORT OF HARD COAL
IMPOIL	IMPORT OF CRUDE OIL
IMPGAS	IMPORT OF NATURAL GAS
IMPURN	IMPORT OF URANIUM
IMPTHO	IMPORT OF THORIUM
STKURN	STOCKPILING OF NATURAL URANIUM
STKUDP	STOCKPILING OF DEPLETED URANIUM
STKPLU	STOCKPILING OF PLUTONIUM
STKU35	STOCKPILING OF U33/U35 MIXED OXIDE
STKLWS	STOCKPILING OF LWR SPENT FUEL
STKHT3	STOCKPILING OF SPENT URN/THO HTR FUEL
STKHT4	STOCKPILING OF SPENT U35/THO HTR FUEL
STKLMS	STOCKPILING OF LMFBR SPENT FUEL

Objective function

The minimisation of total discounted system cost was an objective function used in all scenarios. However, some scenarios comprise a sequence of two or more optimisations, each using a different objective function. The objective function used in the last step of such a sequence is always the minimisation of total discounted system cost. For example, the computation of the SP-1 scenario comprises two runs. The objective function applied in the first is the minimisation of the total amount of imported oil during the time span considered. In the second run, the objective function is the minimising of the total discounted system cost under a constraint, viz. that the total amount of imported oil is not allowed to exceed the value obtained from the first run.

Supply and price of primary fuels

See section 4.2 of this report.

Use of final energy instead of useful energy for each demand sector

The end-use demands are normally specified in terms of useful energy with the efficiencies for the demand devices having a value of less than one. The demands can alternatively be expressed in terms of final energy, in which case efficiencies do not enter the calculations.

For instance, for the transportation sector the second option has been used, and thus the specified demand represents the fuel delivered to the vehicles at the gas stations, that is to say, the engine efficiency does not enter the calculations. However, the model can choose between oil-derived and coal-derived liquid fuels.

The computation of the demand data is discussed in more detail in section 4.3 of this report.

Technology data

Data necessary to characterise technologies (investment cost, operating and maintenance cost, efficiency, starting year, technical lifetime, etc.) are discussed in detail in section 4.4 of this report.

Constraints on implementation of new technologies

There are two main kinds of constraints: bounds on total installed capacity of each technology and bounds on annual investment for each technology. These can be used simultaneously and can be either upper, lower or fixed bounds.

Bounds are discussed in more detail in section 4.4 of this report.

All these inputs, except the objective function, are included in the national data file. The objective function is specified during the particular scenario run.

A standard output includes:

- Primary energy required to satisfy the energy demand specified by the input data.

- Exports and imports of fuels.

- Final energy demand for each sector.

- Installed capacity of conversion technologies.

- Total discounted system cost.

- Total emissions (1).

(1) At present, the work plan has not allowed for the inclusion of environmental data.

- Shadow price, i.e. the marginal cost of an additional unit of a bounded quantity.

Results are shown in section 5 of this report. A considerable programming effort was required to achieve the quality of presentation.

3. SCENARIOS

"Scenarios" are hypothetical sequences of conditions which can modify the structure of an energy system. It is obvious, for example, that the imported crude oil price has a very large influence on the structure of the energy systems of the Western European countries. Therefore a change in the evolution of this price will introduce important modifications to the energy systems. Each possible evolution of this price creates a different scenario. This is just an example; another group of scenarios could be created by considering different policy constraints relative to the implementation of different types of power plants, etc. The main objective of this study is to describe the sensitivity of the Spanish energy system to changes in certain parameters.

3.1 Definition of Scenarios

Excluding the RP-4 scenario, which will be explained below, all scenarios are characterised by two main indicators:

PRICE indicator	: P = total discounted cost of the energy system for the total time considered (45 years)
SECURITY OF SUPPLY indicator	: S = total net oil import over the entire time span

The so-called "PS-scenarios" have been obtained by minimising P with no constraint on S. One of these scenarios has been considered as the base case or reference scenario (PS-1). The number after the two capital letters indicates if the scenario is accelerated or not.

Unaccelerated scenarios

These scenarios have the number 1 after the two capital letters. This means that the date of availability and the constraints on implementation of new technologies are exactly the same as in the reference scenario PS-1.

If these scenarios are represented in the (PS) space, they lie on the PRICE-SECURITY trade-off curve (see Figure 4). The SP scenarios have been obtained by minimising P under the constraint that S is not allowed to exceed a given upper limit S^{*}.

$$S \leq S^{*}$$

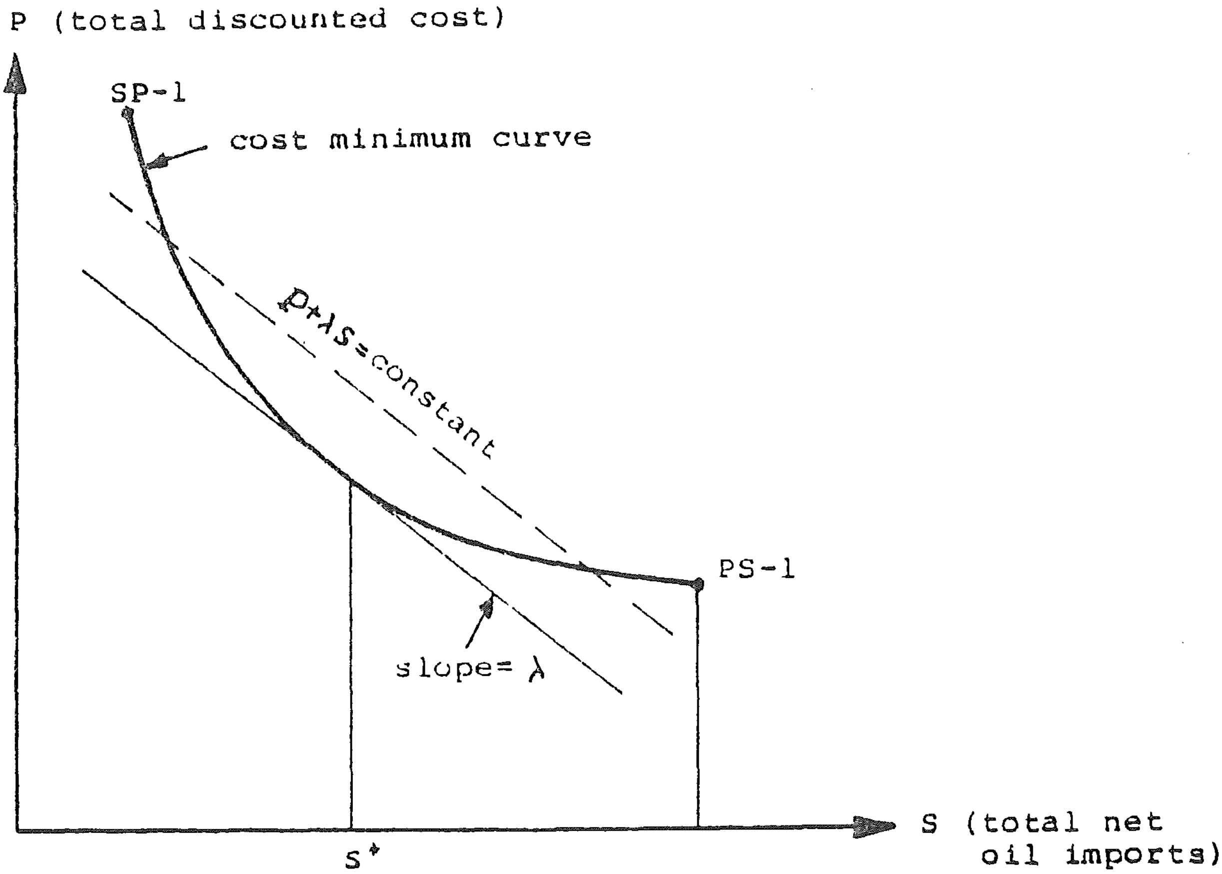

Figure 4: Price-Security Trade-Off Curve

It can be seen in Figure 4 that enforced reduction of net oil imports below the PS-1 point in a scenario study will gradually increase the total discounted system cost, because oil is substituted by more expensive technologies. Progressively larger reductions in oil imports will increase the system cost until a limit point is reached below which it is impossible to reduce oil imports. Below this point the exogenously specified energy demand could not be satisfied for one or more demand sub-sectors. This limit point is the SP-1 scenario.

It is interesting to get scenarios for which a comparison can be made among different countries. The intermediate points on the trade-off curve are defined by the slope λ of the curve, i.e. by the marginal cost of S. The value of this is given by the dual value of the following constraint:

$$S \leq S^{*}$$

Such intermediate points are obtained by minimising, in a first step, the objective function:

$$P + \lambda S$$

and then by minimising, in a second step, the total discounted system cost under the constraint that S is not allowed to exceed the value obtained from the first step.

This procedure permits a meaningful aggregation of results for a group of countries. If two countries have different marginal costs for the security indicator S, the total cost for the group could be reduced without changing the total amount of imported oil for the group, by increasing the imports of the country with the largest value for λ and reducing the imports of the one with the smaller value of λ.

Accelerated scenarios

These scenarios have the number 4 after the two capital letters. They are defined in the same way as unaccelerated scenarios except that a selection of new technologies (depending on the scenario) have their dates of availability advanced by five years. Furthermore, some of these technologies (depending also on the scenario) have their possible implementation levels increased.

Availability dates and implementation levels used for both kinds of scenarios are discussed in more detail in section 4.5 of this report.

Sensitivity case scenarios

The sensitivity case scenarios differ from the others by making different assumptions concerning some or all of: the imported oil price schedule, the imported hard coal price schedule, limitations on nuclear power, and limitations on the availability of fossil energy carriers.

The RP-4 scenario is defined in the same way as PS-4, but with technologies using renewable energy at their highest implementation levels.

The participating countries were divided into two groups. In accordance with the instructions received from Mr. R. Williamson (USA, DOE), Chairman of the IEA Steering Group on Energy R,D & Systems Analysis (1), the Phase A countries (Germany, Japan, Sweden, USA and the United Kingdom) have computed the sixteen scenarios included in the list shown in Figure 5. The Phase B countries (Austria, Belgium, Canada, Denmark, Ireland, Italy, New Zealand, Norway, Spain and Switzerland) have run a minimum of eight scenarios (the ones marked with an asterisk in Figure 5), as decided in the 10th Steering Group Meeting (Stockholm, July 1979).

Besides these eight scenarios, two additional ones are presented in the present Spanish report; the PS-1/LIM NUC and PS-1/COAL C scenarios (the last one does not appear in Figure 5, but has been computed because of the important role played by imported hard coal in the Spanish energy system (see section 5)).

A list of the scenarios presented in this report can be seen in Table 2.

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(1) R. Williamson: Memorandum for Steering Group on Energy Systems Analysis, Cases to be used in Sensitivity Analysis, February 13th, 1979.

R. Williamson: Memorandum for Steering Group on Energy Systems Analysis, Cases to be used in Sensitivity Analysis, April 17th, 1979.

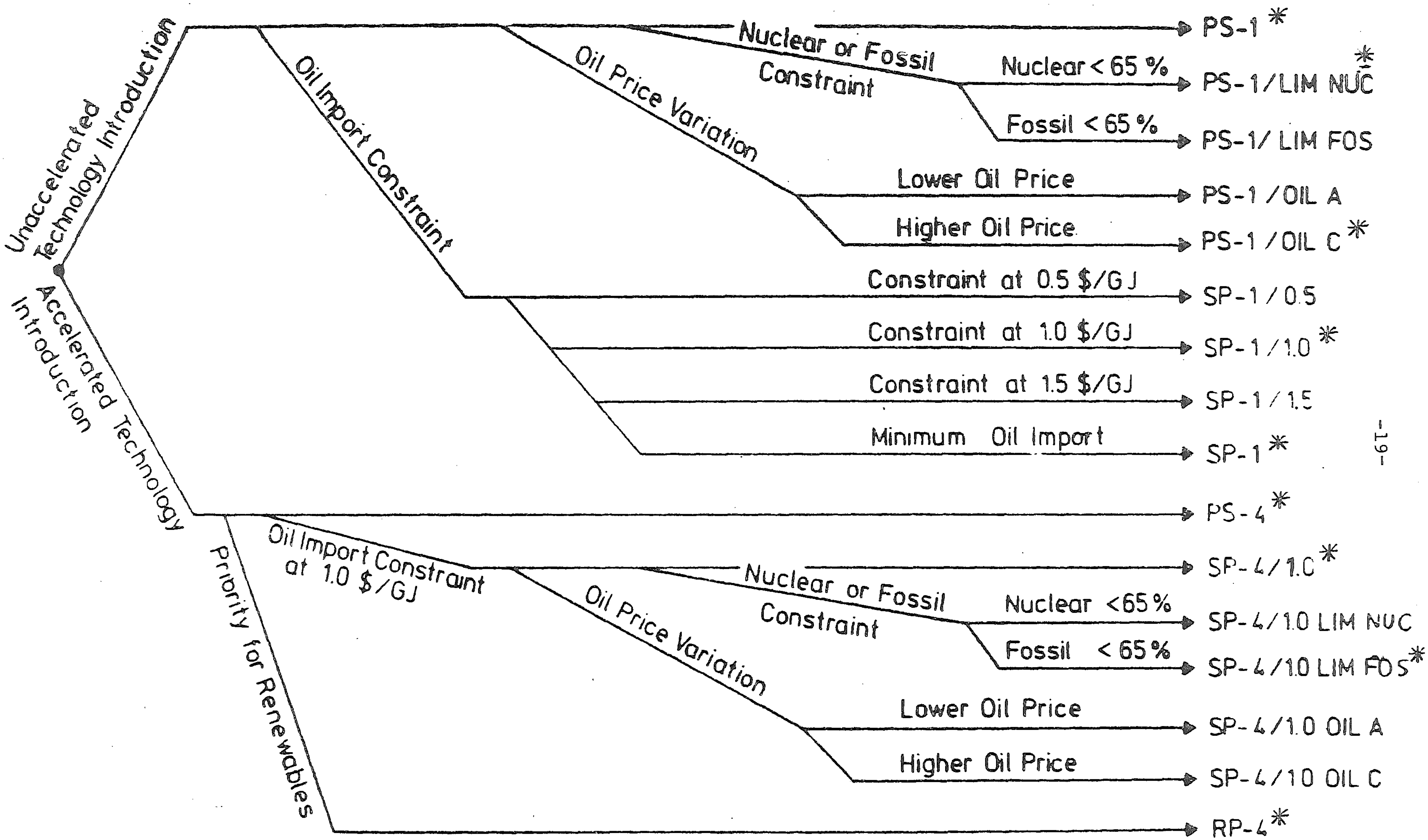

Figure 5: Scenario Overview

a) Unaccelerated case runs	
PS-1	- Reference scenario. Cost minimisation
SP-1	- Cost minimisation at extreme level of oil import reduction.
SP-1/1.0	- Cost minimisation at level of oil import reduction of $ 1.0/GJ shadow price of security indicator.
PS-1/OIL C	- The reference scenario with the oil price schedule C.
PS-1/COAL C	- The reference scenario with the coal price schedule C.
PS-1/LIM NUC	- The reference scenario with total nuclear energy constrained to 65% of that for the reference scenario.
b) Accelerated case runs	
PS-4	- As for PS-1 with acceleration level 4.
SP-4/1.0	- As for SP-1/1.0 with acceleration level 4.
SP-4/LIM FOS	- Total fossil resource use constrained to 80% of that from the PS-4 scenario.
RP-4	- As for PS-4 with the technologies which use renewable energy implemented at their highest levels.

Table 2: List of Computed Scenarios

4. MODEL INPUT DATA

4.1 Objective Function

As explained in the preceeding sections, two or more objective functions can be applied sequentially. Examples of objective functions which can be used are: minimise total system cost, minimise oil imports, minimise use of fossil fuels, etc.

4.2 Supply and Prices of Primary Energy

4.2.1 Coal

a) Hard Coal

The Spanish hard coal resources have been estimated to be approximately 1850 MTCE. Domestic extraction is not sufficient to cover the demand, and therefore the price of imported hard coal plays an important role in the Spanish Energy System. Moreover, the price of domestic coal is much higher than the international one. However, lower bounds have been implemented for political reasons. For the first two time periods, the guidelines contained in the Spanish Energy Plan, which was approved last summer by the Spanish Parliament, have been taken into account. The price for imported hard coal is assumed to increase 2% per year, except for the PS-1/COAL C scenario, which assumes an increase of 3% (see Figure 7).

b) Brown Coal

Total domestic reserves of this resource are approximately 630 MTCE, and two different classes of brown coal are distinguished. It has been assumed that one class will be exhausted by the year 2005. Until now, brown coal has only been used for electricity generation, but the model output shows that, in future, brown coal is used for both electricity and synthetic fuels production.

Imported brown coal has not been considered in this study.

4.2.2 Crude oil

Domestic crude oil reserves have been estimated at about 70 MTCE, considering only the oil fields actually in exploitation. Taking into account the amount of oil which is presently extracted from these fields, domestic oil has been assumed to be exhausted by the year 1990.

Imported oil comes mainly from several Arabian countries. Assumed prices for imported oil are shown in Figure 6. The standard price schedule applied to most scenarios is schedule B, and price schedules A and C are used for sensitivity cases only. These oil price assumptions have been given by the IEA Steering Group on RD&D Strategy (Document IEA/CRD/M(78)1), starting with $\$_{(77)}$ 13.0/bbl for 1977 FOB Persian Gulf. For CIF prices at Western European harbours, $\$_{(75)}$ 0.3/GJ transportation costs have been added.

4.2.3 Natural gas

Domestic availability of natural gas is also very low. It has been calculated in the same way as for crude oil, with reserves being depleted at approximately the same time. The assumed price for imported natural gas is shown in Figure 7. It has been calculated by assuming that the price of imported natural gas will remain at 0.8 times that of imported crude oil.

4.2.4 Uranium

Total domestic reserves have been estimated at about 60,000 T, available as enriched uranium. Yearly mining is assumed to grow until the year 2010 and to decrease afterwards. The bounds have been implemented taking into account existing fields only and because of this the domestic production decreases after the year 2010. Outputs from the model show that domestic production is not enough to cover the demand because the installed capacity of nuclear power plants becomes very large in almost all scenarios. The assumed price for imported natural uranium can be seen in Figure 7. The price is estimated to increase at 3% per year.

4.2.5 Renewables

The most important renewable resource in the Spanish Energy System is hydropower.

Fuel Prices

Imported Crude Oil Price

($\$_{75}$/GJ)	1980	1990	2000	2010	2020
Schedule A	2.36	2.85	3.16	3.65	3.96
Schedule B	2.36	2.85	4.28	5.71	7.46
Schedule C	2.36	3.48	5.86	7.47	7.47

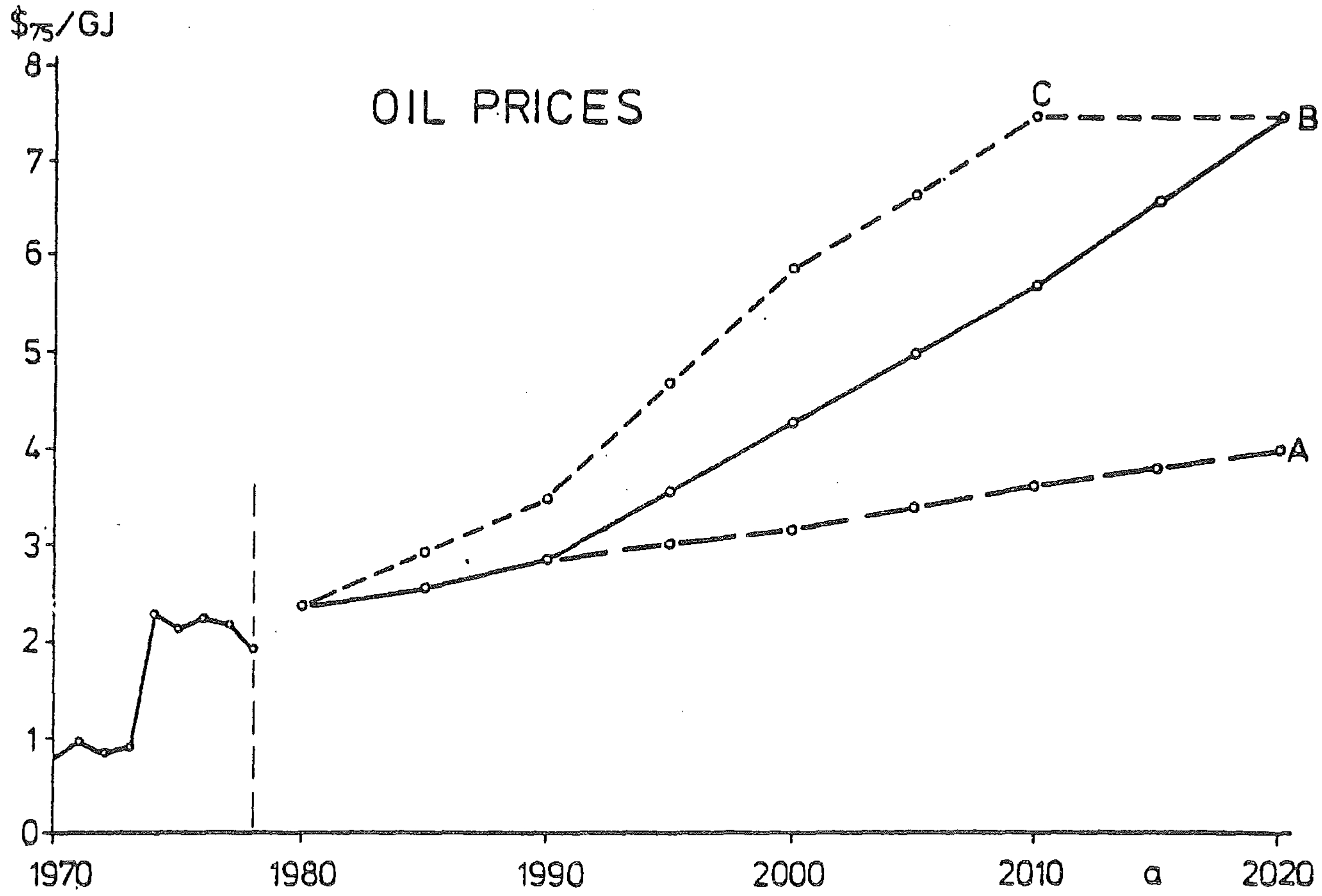

Figure 6 : Oil Prices

Prices of Natural Gas, Hard Coal, Natural Uranium

($\$_{75}$/GJ)	1980	1990	2000	2010	2020
Imported Natural Gas (Pipeline + LNG)	1.88	2.28	3.42	4.56	5.97
Imported Hard Coal	1.30	1.52	1.86	2.26	2.76
Domestic Hard Coal	2.50	3.08	4.79	6.49	8.81
Import. Hard Coal Schedule C	1.30	1.75	2.35	3.16	4.24
Imported Natural Uranium ($\$_{75}$ / Gramme)	0.104	0.128	0.200	0.272	0.360

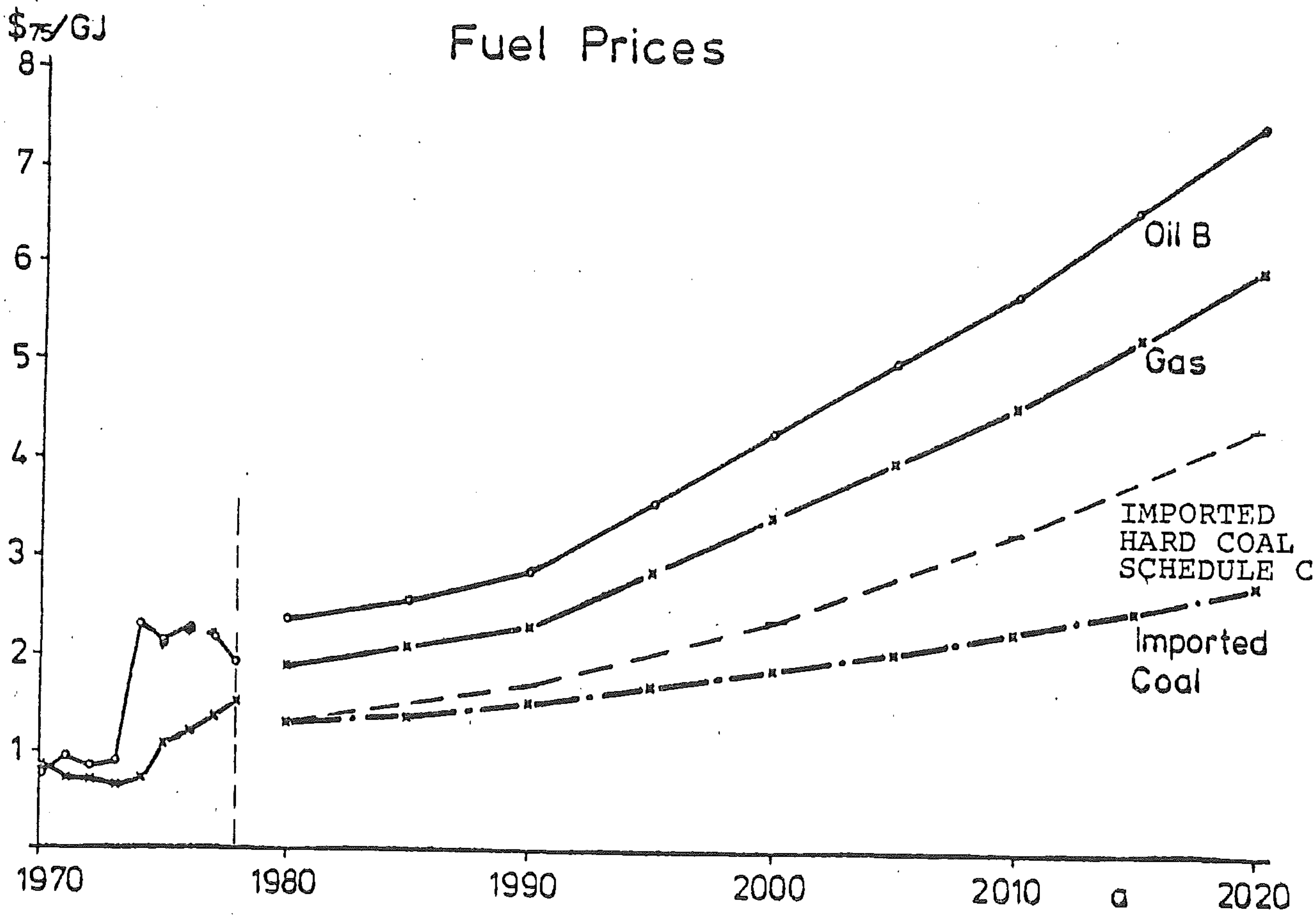

Figure 7 : Fuel Prices

The average hydroelectric production of the Spanish hydropower system is, at present, in the neighbourhood of 36.000 GWh. Installed capacity has been continuously increased during the last fifteen years and is, at the present time, about 13.500 MW. Tables 3 and 4 show the evolution of electricity generation and installed capacity of electric power plants for the last thirteen years. Naturally, the structure of generation is influenced by the hydrology of the corresponding year.

4.3 Demand Data

Demand projections have been made considering the following four demand sectors:

- Industry
- Transportation
- Non-energy use
- Residential and commercial

Each sector has been sub-divided into the following sub-sectors:

- Industry	Iron and steel industry Other industry
- Transportation	Road transport Rail, air and ship transport
- Residential and commercial	Space heating, single family dwellings Space heating, multi-family dwellings Warm water, all users Lighting and appliances, all users
- Non-energy use	Non-energy use

This classification has been made taking into account the availability and degree of disaggregation of numerical data.

For industry, transportation and non-energy use sectors, the demand

YEAR	FROM HYDROELECTRIC POWER PLANTS		FROM FOSSIL POWER PLANTS		FROM NUCLEAR POWER PLANTS		TOTAL	
	10^6 kWh	%	10^6 kWh	%	10^6 kWh	%	10^6 kWh	%
1966	27278	72	10421	28	-	-	37699	100
1967	22680	56	17957	44	-	-	40637	100
1968	24428	53	21366	47	57	-	45851	100
1969	30691	59	20604	40	829	1	52124	100
1970	27959	49	27608	49	923	2	56490	100
1971	32747	52	27246	44	2523	4	62516	100
1972	36458	53	27695	40	4751	7	68904	100
1973	29524	39	40203	53	6545	9	76272	100
1974	31347	39	42285	52	7225	9	80857	100
1975	26448	32	48490	59	7544	9	82482	100
1976	22508	25	60759	67	7555	8	90822	100
1977	40742	43	46537	50	6525	7	93804	100
1978	41625	42	50071	50	7649	8	99345	100

TABLE 3. ELECTRICITY PRODUCTION

YEAR	HYDROELECTRIC POWER PLANTS	FOSSIL POWER PLANTS	NUCLEAR POWER PLANTS	T O T A L
1966	7680	3457	-	11137
1967	8227	4671	-	12898
1968	8543	5292	153	13988
1969	9335	6165	153	15653
1970	10883	6888	153	17924
1971	11057	7403	613	19073
1972	11136	9615	1120	21871
1973	11470	10617	1120	23207
1974	11841	11376	1120	24337
1975	11954	12393	1120	25467
1976	12497	12974	1120	26591
1977	13096	13334	1120	27550
1978	13504	13573	1120	28197

TABLE 4. INSTALLED CAPACITY OF SPANISH POWER PLANTS (MW)

has been specified in terms of final energy, and for the residential and commercial sectors in terms of useful energy. This method was adopted because of the difficulty in estimating the efficiencies for the considerable number of industrial processes. Moreover, the efficiencies of internal combustion engines used for transportation are not constant, depending among other factors on the engine r.p.m. Rail, air and ship transport have been considered together because it is not logical to allow competition between them (for example, it is not always possible to transport goods between two points by choosing betweeen rail, ship or plane if one point is not situated on the coast, in the case of ship transport, or has no airport, in the case of air transport). In addition, a jet uses only herosene while a train can run on either diesel, or electricity, if the line is electrified.

The plot given in Figure 8 shows the projections for the demand sectors. Numerical values can be seen in Table 5.

4.4 Technology Data

The MARKAL model makes an optimisation according to a specific objective function and constraints and selects a certain technology mix from all the options available in the data base.

The technology input data supplied by the user must adequately reflect the present situation of a country, and must also include data concerning new technologies.

The technology input data applied to scenario computations has been collected by the IEA Systems Analysis Staff (1). Therefore, according to the guidelines and instructions of the IEA Steering Group on Energy RD&D Systems Development, the national data sets

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(1) - Technology Review Report, revised, IEA Systems Analysis Project, September 1979 (currently being corrected for final edition).
- Technology Data Handbook, IEA Systems Analysis Project at Jülich, September 1979 (currently being completed and revised for final edition).
- MARKAL, Spanish data set.

SINGLE SCENARIO FOR SPAIN RUN TSP10M SCENARIO: PS-1 DATE: 11/11/79

TABLE 19: USEFUL ENERGY BY SECTORS (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
935.4	1089.8	1235.4	1367.1	1502.2	1616.2	1738.2	1879.2	2015.2	1 - INDUSTRY
227.6	264.7	289.1	319.3	348.0	375.5	398.9	422.6	445.5	2 - RES AND COMM
720.0	828.0	919.8	1008.0	1078.2	1144.8	1207.8	1256.4	1301.4	3 - TRANSPORTATION
190.0	214.7	243.2	266.0	290.7	305.9	321.1	338.2	355.3	4 - NON ENERGY USE
2073.0	2397.2	2687.5	2960.4	3219.1	3442.4	3666.0	3896.4	4117.4	***** T O T A L *****

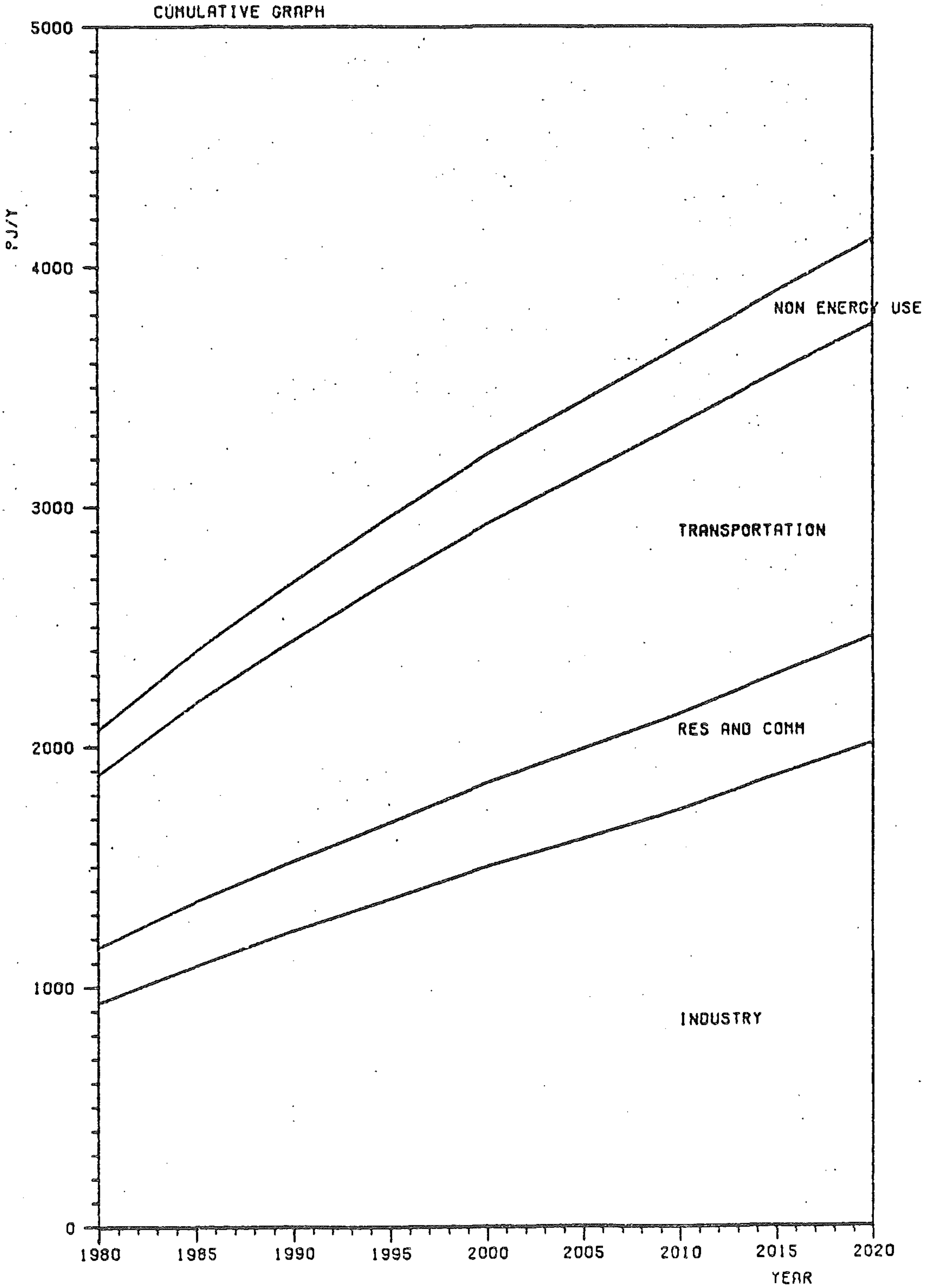


Figure 8 : Demand Projections

Unit : PJ

	INDUSTRIAL SECTOR					TRANSPORTATION SECTOR				RESIDENTIAL & COMMERCIAL SECTOR					AGRICULTURE	
Year	Iron-Steel	Chemical	Cement	Other	Total	Air	Road	Other	Total	Space Htg.[x]	Space Htg.[xx]	Warm water	Other	Total		TOTAL SECTORS
1980	200	154	114	491	959	55	432	125	612	32	84	52	152	320	113	2004
1985	222	182	125	561	1090	71	512	125	708	38	100	62	171	371	126	2295
1990	251	212	132	640	1235	79	583	125	787	44	116	71	187	418	139	2579
1995	285	244	112	726	1367	94	640	125	859	50	133	79	203	465	152	2843
2000	317	279	99	807	1502	101	694	125	920	56	149	87	218	510	163	3095
2005	343	313	90	870	1616	118	737	125	980	60	164	95	232	551	173	3320
2010	370	345	88	935	1738	124	783	125	1032	64	179	102	246	591	182	3543
2015	416	377	88	998	1879	129	819	125	1073	68	192	108	258	626	190	3768
2020	465	408	88	1054	2015	145	846	125	1116	71	205	113	270	659	196	3986

[x] Single family
[xx] Multi family

TABLE 5. FINAL DEMAND PROJECTIONS

for all countries participating in the project are based on common ground rules. The ground rules are outlined at the end of this sub-section.

The MARKAL model requires that each technology be described by the following set of quantitative data elements:

a) Physical parameters

START : Time period of commercial availability.

LIFE : Technical lifetime.

AF : Availability factor. Fraction of year during which the plant is available, that is one minus scheduled maintenance (AF can vary with the season and time of day).

EFF : Efficiency (total output divided by total input).

For coupled production plants, which produce both electricity and heat, additional data elements are required in order to specify the fraction of the output energy which is electricity. For a pass-out turbine system the additional data required are:

CEH : Ratio of electricity lost to useful heat gained.

ECM : Maximum value of the ratio of electricity lost to heat gained.

For a back-pressure turbine the additional datum is:

REH : Ratio of electricity production to heat production.

In a back-pressure turbine system it is not possible to vary the ratio of electricity production to heat production. However, in a pass-out turbine system, the ratio can be varied to meet the particular requirements for electricity and heat.

Process systems (i.e. non-electric and non-district heating technologies) require the following data:

INP (ENC)
OUT (ENC) : These two parameters specify the fractional input and output of each energy carrier. The efficiency is the sum of outputs divided by the sum of inputs.

The following data elements are optional:

RESID : Existing technologies require additional data elements which specify the capacity existing at the starting time (1980) which is available in each time period.

b) Economic factors

INVCOST : Total capital investment costs per unit of capacity.

FIXOM : Fixed annual operating and maintenance costs.

VAROM : Variable annual operating and maintenance costs.

DELIV : Delivery cost of fuels to the respective technology (optional).

For the compilation of technology data the following set of ground rules has been observed:

- All costs are expressed in constant 1975 US dollars. Costs originally expressed in other currencies have been deflated to 1975 according to national inflation rates and converted to dollars at 1975 average exchange rates. In a few cases (not applicable to Spain), adjustments were required to take into account currency revaluations.

- Capital investment costs include interest during construction. A discount rate of 6% per annum in real terms has been used.

- Capital costs are referred to the output of conversion technologies (for instance $/kWe net electrical output for electric power plants) and to input capacities for processes (for instance $/GJ/year input crude oil to refineries).

- Taxes, subsidies and profits have not been included in the capital and operating cost calculations, because they have been considered as country-dependent items. This rule does not apply to incentives offered for export.

- Fixed operating and maintenance costs (FIXOM) include insurance premiums and other specified real expenses (excluding taxes) required by law in the individual countries (for example, payments for waste disposal or decommissioning).

- Capacities are expressed in units of gigawatts net electrical output (GWe) for electric systems and peta-joules (10^{15} joules) per year for non-electric systems.

- Energy flows are expressed in units of peta-joules per year unless otherwise noted.

- The energy content of energy carriers (coal, gas, and oil-based fuels) are expressed in terms of net calorific value which means that the heat of condensation of water produced during combustion is not included in the calorific content of the fuel.

- Efficiencies are understood to be net efficiencies.

- The contribution of nuclear and renewable systems to total primary energy is calculated as fossil fuel equivalent (FEQ), which is the fossil fuel that would have been consumed to supply the same services. Numerical values adopted for FEQ for electricity production systems are listed in Table B2, page 103, of OECD's World Energy Outlook, 1977, for the years 1980 and 1985. The physical efficiencies for nuclear and renewable systems do not enter the calculations of the model except for calculating net heat release to the environment (which has been omitted up to now).

4.5 Constraints

4.5.1 Primary energy

a) Domestic

It has already been indicated that, for social reasons, lower bounds have been established for domestic fossil primary energy supply.

For all scenarios it has been assumed that hydropower potential available in each time period is fully exploited.

b) Imports

In general, primary energy imports are unconstrained. The first two time periods, in which lower bounds have been implemented according to the guidelines contained in the Energy Program of the Spanish Government, are exceptions. These guidelines for imports refer to natural gas, oil and hard coal.

4.5.2 Electricity production

In the above-mentioned Energy Program, regulations are contained which prohibit the construction of new oil power plants, except for small diesel plants which are the only option in some cases, for example for some islands in the Canary and Balear archipelago. The decisions already adopted by the Spanish Parliament concerning new plants currently planned or under construction have also been adhered to. These refer mainly to nuclear power plants and fossil power plants using hard coal and domestic brown coal.

4.5.3 Conservation

The Energy Program contains specifications about heat transmission losses in new buildings. These have also been taken into account.

4.5.4 Constraints on implementation of new technologies

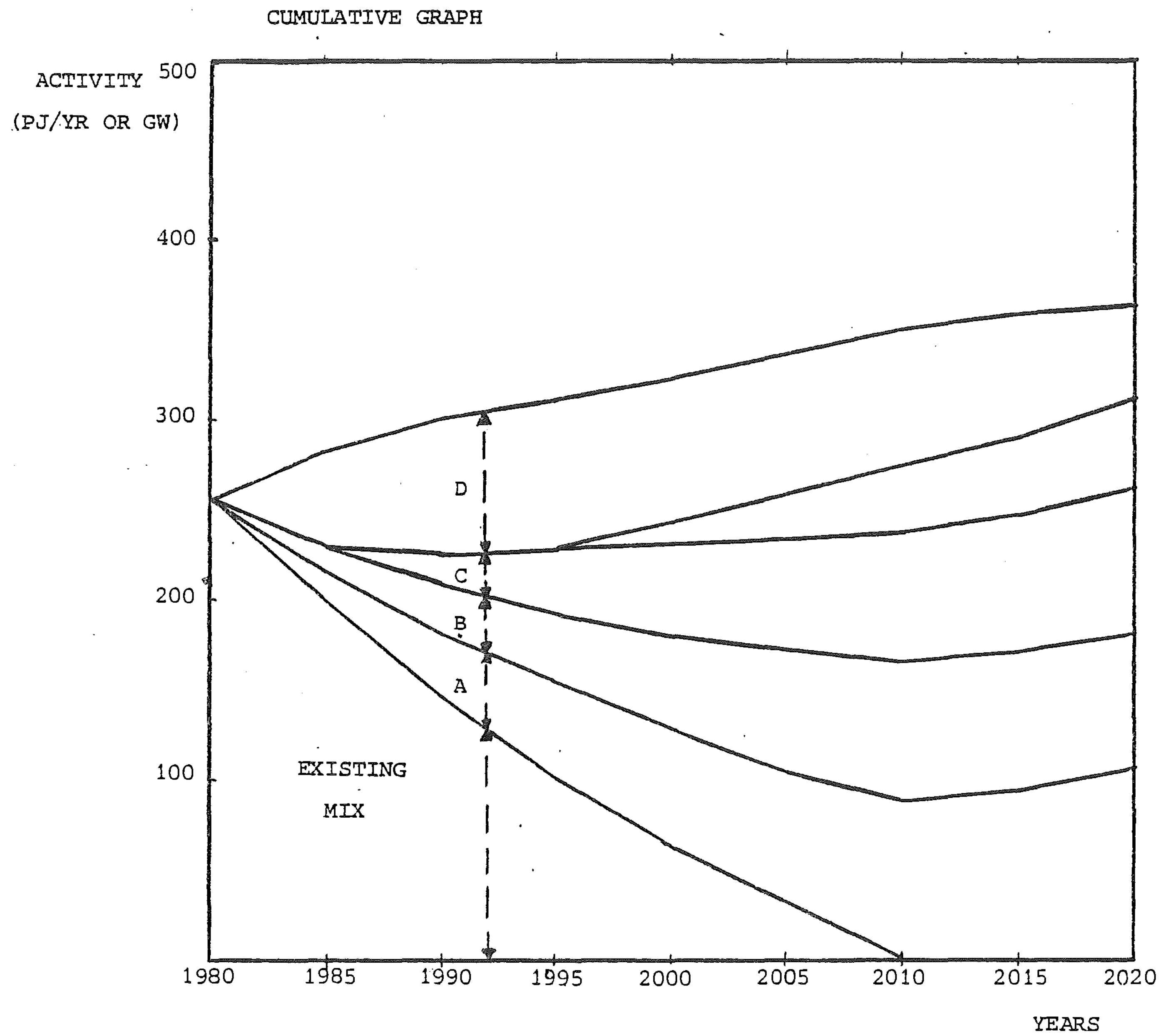
In this sub-sector it is briefly discussed why new technologies must be constrained and at which level the respective constraints have been implemented.

Figure 9 shows an example of the inputs required for one demand sector during the whole time span. For this demand sector the exogenously-given demand for useful energy is satisfied for each time period.

At the beginning of the scenario time frame, the existing stocks of demand devices must be taken into account. These stocks gradually disappear as they become obsolete. They must be exogenously given by the user and are called existing mix.

As can be seen in Figure 9, for each time period, the difference between the total demand and the declining existing mix is satisfied by MARKAL with an optimal mix of technologies which is selected from the options available in the data base.

It is then necessary to implement bounds for these options because otherwise the model would choose the cheapest available option (if the objective function is the total system cost) and would satisfy the entire difference between demand and existing mix using that option only. Therefore an unrealistic solution would be obtained because even though, for example, the cheapest option for space heating is solar, it is not logical that all the space heating demand of a country be satisfied by solar space heating. Insolation levels depend on location and also weather, season and time of day.



A, B, C, D ..... Activities of technologies chosen by MARKAL to cover the demand

Figure 9. Example of Optimization

Other constraints are of a technical nature. For example, it must be specified that washing machines consume electricity, otherwise the model could choose diesel motors to run them!

The constraints for all new technologies considered in this study are shown in Table 6.

IBONDUP IBONDLO IBONDFX	Constraints on investment
BOUNDUP BOUNDLO BOUNDFX	Constraints on total capacity
U	For unaccelerated scenarios
A	For accelerated scenarios

TABLE 6. CONSTRAINTS ON IMPLEMENTATION OF NEW TECHNOLOGIES

MARKAL CODE	TECHNOLOGY	START YEAR	TYPE OF BOUND	UNIT	1980	1985	1990	1995	2000	2005	2010	2015	2020
R2A	Space heating single family dwelling, electric heat pump	1990	U IBONDUP	PJ/PER	-	-	6	6	6	6	6	6	6
		1985	A IBONDUP	PJ/PER	-	4	6	8	9	9	10	10	10
R2B	Space heating single family dwelling, gas heat pump	1990	U IBONDUP	PJ/PER	-	-	3	3	3	3	3	3	3
		1985	A IBONDUP	PJ/PER	-	3	5	5	5	5	5	5	5
R2D	Space heating single family dwelling, solar	1980	U IBONDUP	PJ/PER	1	3	5	10	10	10	10	10	10
		1980	A IBONDUP	PJ/PER	1	3	6	10	12	14	16	18	20
R5D	Warm water all users, solar	1980	U IBONDUP	PJ/PER	1	3	8	15	17	18	20	20	20
		1980	A IBONDUP	PJ/PER	1	5	10	16	20	22	25	30	30
RTA	Space heating multi-family dwelling, electric heat pump	1990	U IBONDUP	PJ/PER	-	-	9	9	9	9	9	9	10
		1985	A IBONDUP	PJ/PER	-	1	10	10	12	12	14	16	16
RTB	Space heating multi-family dwelling, gas heat pump	1990	U IBONDUP	PJ/PER	-	-	3.5	3.5	3.5	3.5	3.5	3.5	3.5
		1985	A IBONDUP	PJ/PER	-	1	5	5	5	5	5	5	5
T8Ø	Road transport, electric	1990	U BOUNDUP	PJ	-	-	0.8	1.5	4.4	7.5	15	24	30
		1985	A BOUNDUP	PJ	-	1	5	10	15	20	30	40	45
T8V	Road transport, hydrogen	1995	U BOUNDUP	PJ	-	-	-	0.3	1.5	3	5	9	15
		1990	A BOUNDUP	PJ	-	-	0.5	3	5	10	15	20	25
SØI	Hard coal Lurgi gasification	1990	U IBONDUP	PJ/PER	-	-	15	60	80	90	90	100	100
		1985	A IBONDUP	PJ/PER	-	25	40	75	90	110	110	130	130
SØ2	Hard coal to medium BTU gas	1995	U IBONDUP	PJ/PER	-	-	-	15	60	80	90	90	100
		1990	U IBONDUP	PJ/PER	-	-	25	70	100	120	140	140	150

TABLE 6. CONSTRAINTS ON IMPLEMENTATION OF NEW TECHNOLOGIES - CONTINUED

MARKAL CODE	TECHNOLOGY	START YEAR	TYPE OF BOUND	UNIT	1980	1985	1990	1995	2000	2005	2010	2015	2020
SØ4	Hard coal Lurgi gasification and methanol production	1995	U IBONDUP	PJ/PER	-	-	-	3	10	15	20	25	30
		1990	A IBONDUP	PJ/PER	-	-	3	10	20	30	40	40	50
SØA	Hard coal nuclear hydrogasification	1995	U IBONDUP	PJ/PER.	-	-	-	20	55	80	110	110	110
		1995	A IBONDUP	PJ/PER	-	-	-	30	70	100	130	130	130
SØB	Hard coal nuclear steam gasification plant	1995	U IBONDUP	PJ/PER	-	-	-	20	55	80	110	110	110
		1995	A IBONDUP	PJ/PER	-	-	-	30	70	100	130	130	130
SØF	Hard coal liquefaction-hydrogenation	1995	U IBONDUP	PJ/PER	-	-	-	20	55	80	110	110	110
		1990	A IBONDUP	PJ/PER	-	-	20	50	80	110	140	150	150
SØG	Hard coal liquefaction Fischer-Tropsch	1995	U IBONDUP	PJ/PER	-	-	-	15	40	60	80	80	80
		1990	A IBONDUP	PJ/PER	-	-	25	50	80	100	100	120	120
S11	Brown coal Lurgi gasification	1990	U IBONDUP	PJ/PER	-	-	10	15	40	60	80	80	80
		1985	A IBONDUP	PJ/PER	-	10	25	50	80	100	100	120	120
S1A	Brown coal nuclear hydrogasification	1995	U IBONDUP	PJ/PER	-	-	-	20	55	80	110	110	110
		1995	A IBONDUP	PJ/PER	-	-	-	30	70	100	130	130	130
S8Ø	Hydrogen production from water electrolysis	1990	U IBONDUP	PJ/PER	-	-	4	10	10	10	10	10	10
		1985	A IBONDUP	PJ/PER	-	6	10	15	15	15	15	15	15
EØE	Hard coal in situ gasification for electricity production	1990	U IBONDUP	GW/PER	-	-	0.15	0.32	0.32	0.32	0.32	0.32	0.32
		1990	A IBONDUP	GW/PER	-	-	0.15	0.32	0.5	0.5	0.5	0.5	0.5

TABLE 6.CONSTRAINTS ON IMPLEMENTATION OF NEW TECHNOLOGIES - CONTINUED

MARKAL CODE	TECHNOLOGY	START YEAR	TYPE OF BOUND	UNIT	1980	1985	1990	1995	2000	2005	2010	2015	2020
E25	HTR nuclear power	2000	U IBONDUP	GW/PER	-	-	-	-	0.5	1	1	2	3
	plant	1995	A IBONDUP	GW/PER	-	-	-	0.2	0.7	1.2	1.2	2.5	4
E26	LMFBR nuclear	2000	U IBONDUP	GW/PER	-	-	-	-	0.5	1	1.2	1.5	2
	power plant	1995	A IBONDUP	GW/PER	-	-	-	0.2	0.7	1.2	1.5	1.8	2.4
E28	Fusion electric	2025	U -	- -	-	-	-	-	-	-	-	-	-
	power plant	2025	A -	- -	-	-	-	-	-	-	-	-	-
E94	Gas fuel cell	1990	U IBONDUP	GW/PER	-	-	0.2	1	1	1	2	2	2
	electric	1990	A IBONDUP	GW/PER	-	-	0.2	1	1	1	2	3	3
E4B	Dispersed solar	1990	U IBONDUP	GW/PER	-	-	0.2	0.2	0.25	0.5	0.75	1.25	1.5
	photo-electric	1990	A IBONDUP	GW/PER	-	-	0.2	0.4	0.5	1	1	1.5	2
E34	Central solar	1995	U IBONDUP	GW/PER	-	-	-	0.1	0.1	0.2	0.5	0.8	1.3
	thermal electric	1995	A IBONDUP	GW/PER	-	-	-	0.15	0.20	0.50	1	1.5	2
EØ6	Hard coal	1990	U IBONDUP	PJ/PER	-	-	0.5	1	1	1	1	1	1
	combined cycle	1990	A IBONDUP	PJ/PER	-	-	0.5	1	1	1	1	1	1
	power plant												

5. RESULTS

The different scenario types have already been defined in section 3 of this report, as well as the trade-off curve concept.

The long time span considered and the large number of different technologies to be analysed generate a large amount of information. It is difficult to display the results in a condensed form.

In sub-section 5.1 the trade-off curve and its corresponding values are shown. In sub-section 5.2 a single scenario report presents the following items for each scenario:

- Primary Energy by Fuel

- Final Energy by Fuel

- Electricity Production by Technology

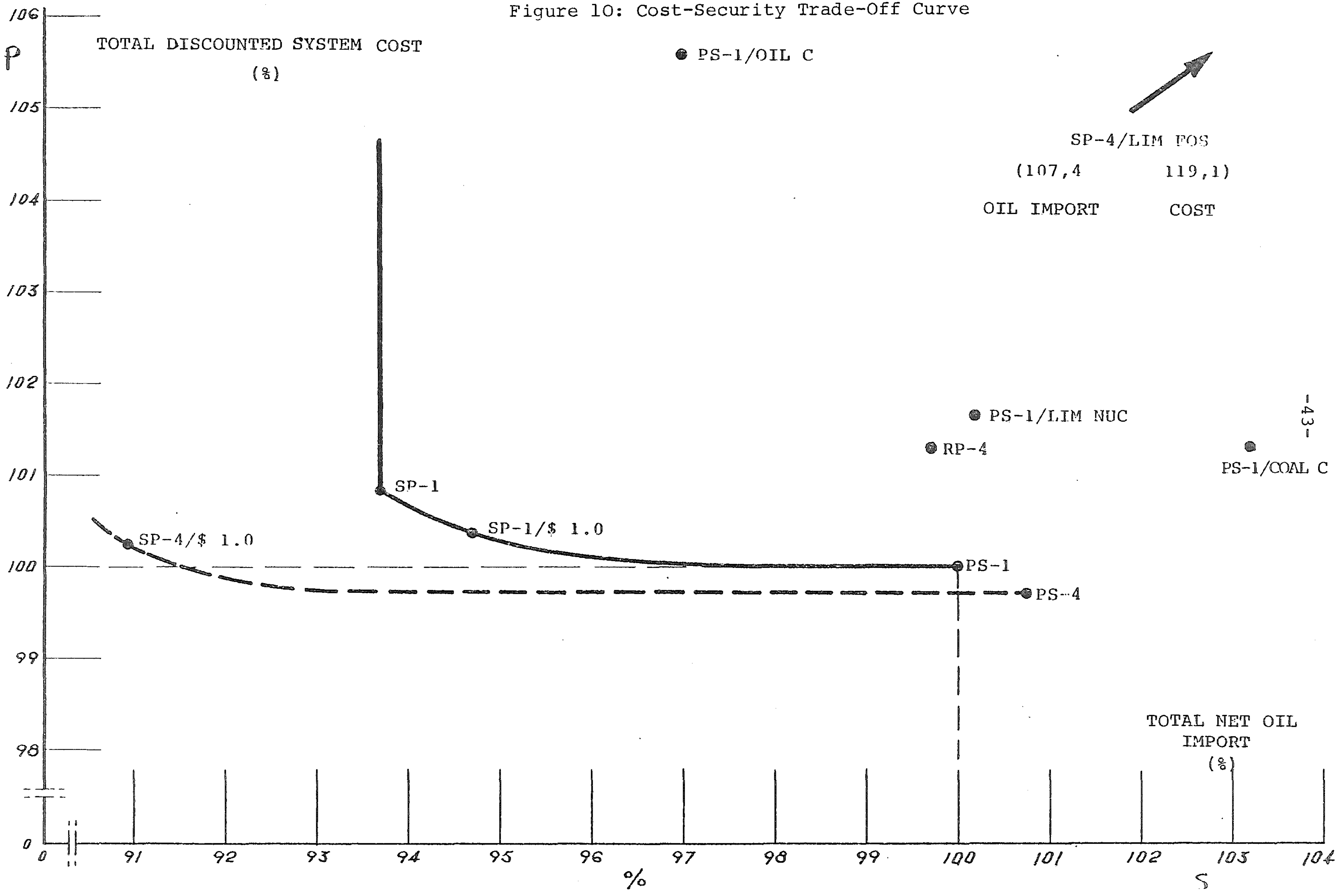
In sub-section 5.3 each particular item is shown on one page for all scenarios.

5.1 Trade-Off Curve

The following table shows, for each scenario, the values of total system cost and total amount of imported oil. The trade-off curve, referring to the PS-1 scenario (base case) is shown in Figure 10.

SCENARIO	TOTAL SYSTEM COST (M$)	TOTAL NET OIL IMPORT (PJ)	SHADOW PRICE OF SECURITY INDICATOR ($/GJ)
PS-1	319861.9	78330.1	-
PS-1/OIL C	337629.7	75973.5	-
SP-1 ($1.0/GJ)	321138.3	74144.4	1.09
SP-1 *	322333.7	73400.7	6.35
PS-4	318924.7	79046.9	-
SP-4 ($1.0/GJ)	321012.9	71202.8	0.99
SP-4/LIM FOS	381122.4	84128.1	-
RP-4	323915.2	78175.7	-
PS-1/COAL C	323906.8	80811.2	-
PS-1/LIM NUC	324974.7	78472.2	-

Figure 10: Cost-Security Trade-Off Curve



5.2 Overview of Scenarios

The following tables and the corresponding graphs show the composition of:

- Primary Energy by Fuel

- Final Energy by Fuel

- Electricity Production by Technology

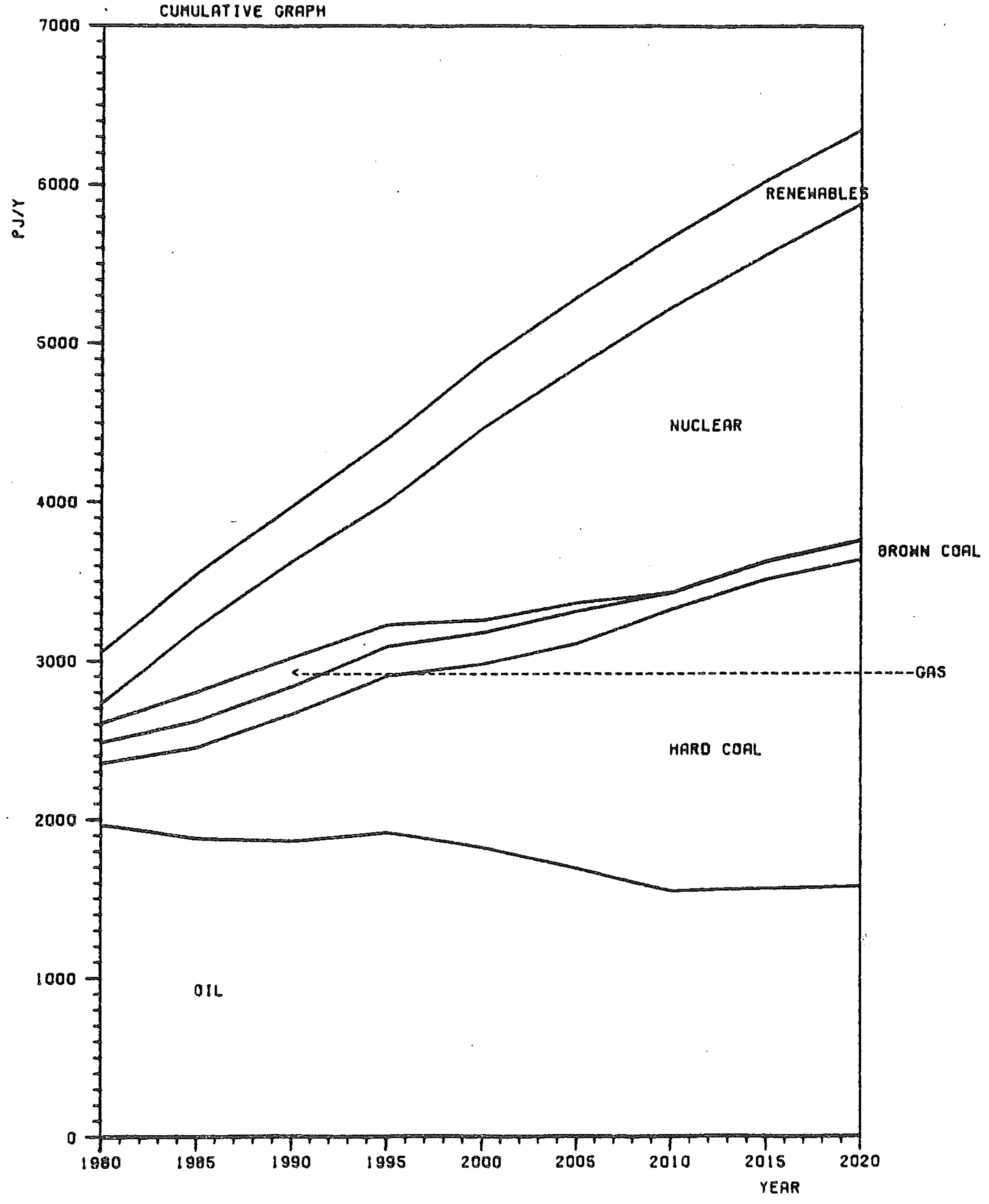
for all the considered scenarios.

SINGLE SCENARIO FOR SPAIN RUN TSP10H SCENARIO: PS-1 DATE: 11/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1880.5	1863.2	1916.8	1823.3	1629.6	1546.2	1560.6	1571.7	1 - OIL
384.0	572.1	799.5	986.9	1157.1	1419.5	1777.7	1953.4	2062.5	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3 - BROWN COAL
120.3	180.3	180.7	138.9	81.5	52.4	0.0	0.0	0.0	4 - GAS
124.5	404.7	607.0	774.1	1208.6	1490.7	1797.4	1934.5	2125.4	5 - NUCLEAR
326.0	338.9	347.8	398.3	419.7	440.0	445.3	466.5	467.9	6 - RENEWABLES
3055.2	3546.5	3974.2	4401.3	4886.8	5296.3	5672.2	6028.2	6340.2	T O T A L

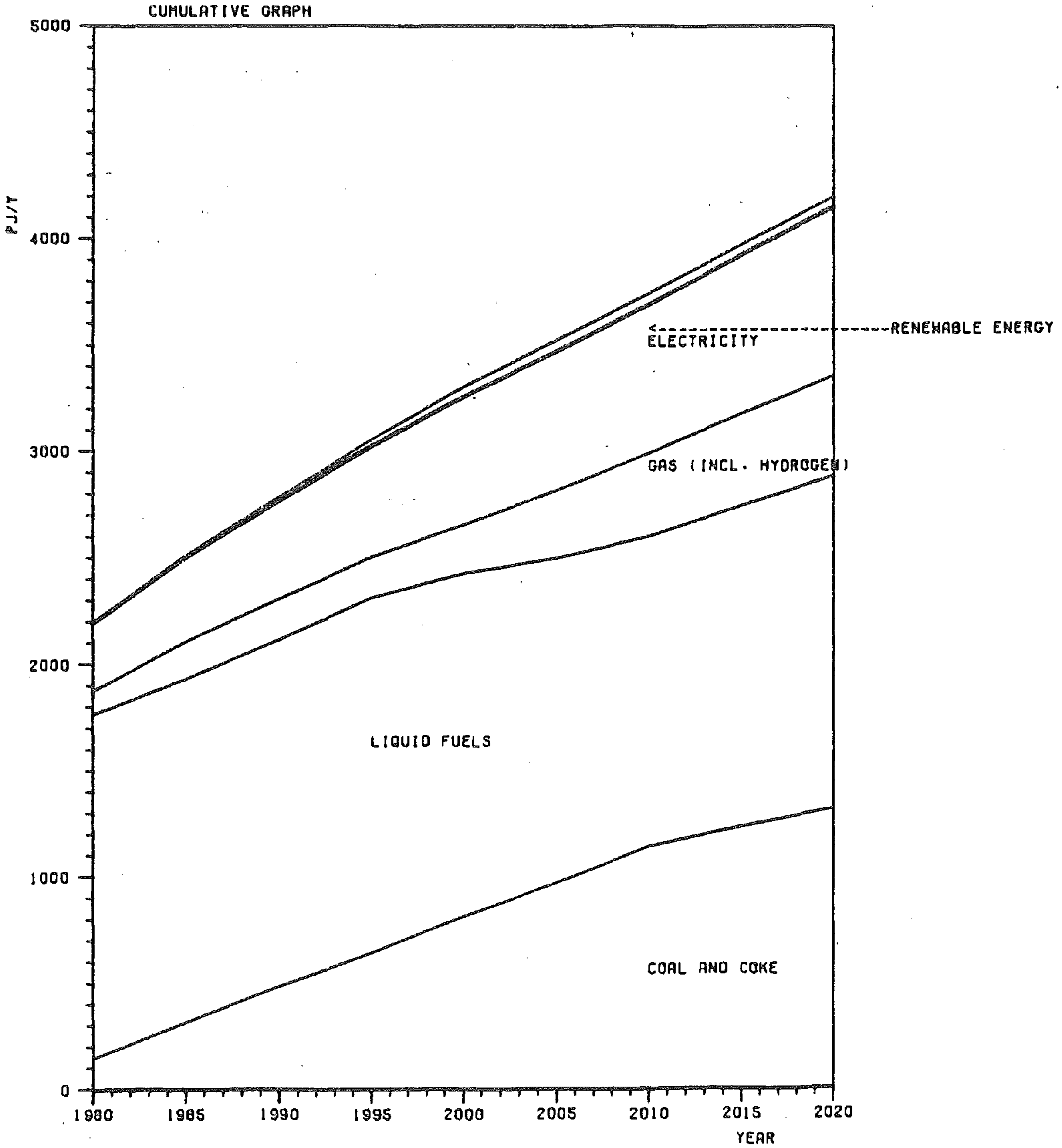
CUMULATIVE GRAPH



SINGLE SCENARIO FOR SPAIN RUN TSP10M SCENARIO: PS-1 DATE: 11/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
148.4	318.4	485.3	643.5	813.8	971.7	1141.4	1232.2	1317.3	1	- COAL AND COKE
1614.5	1612.3	1631.7	1669.4	1612.8	1525.2	1457.2	1511.6	1565.0	2	- LIQUID FUELS
110.2	178.1	192.2	191.5	227.3	321.8	392.7	432.2	472.0	3	- GAS (INCL. HYDROGEN)
320.8	396.8	463.2	522.0	605.7	654.2	699.2	748.9	796.7	4	- ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	- PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	- DISTRICT HEAT
0.0	5.0	17.4	31.4	45.4	51.6	51.6	49.2	47.5	7	- RENEWABLE ENERGY
2193.9	2510.6	2789.8	3067.8	3305.0	3524.5	3742.1	3974.1	4198.5		***** T O T A L *****

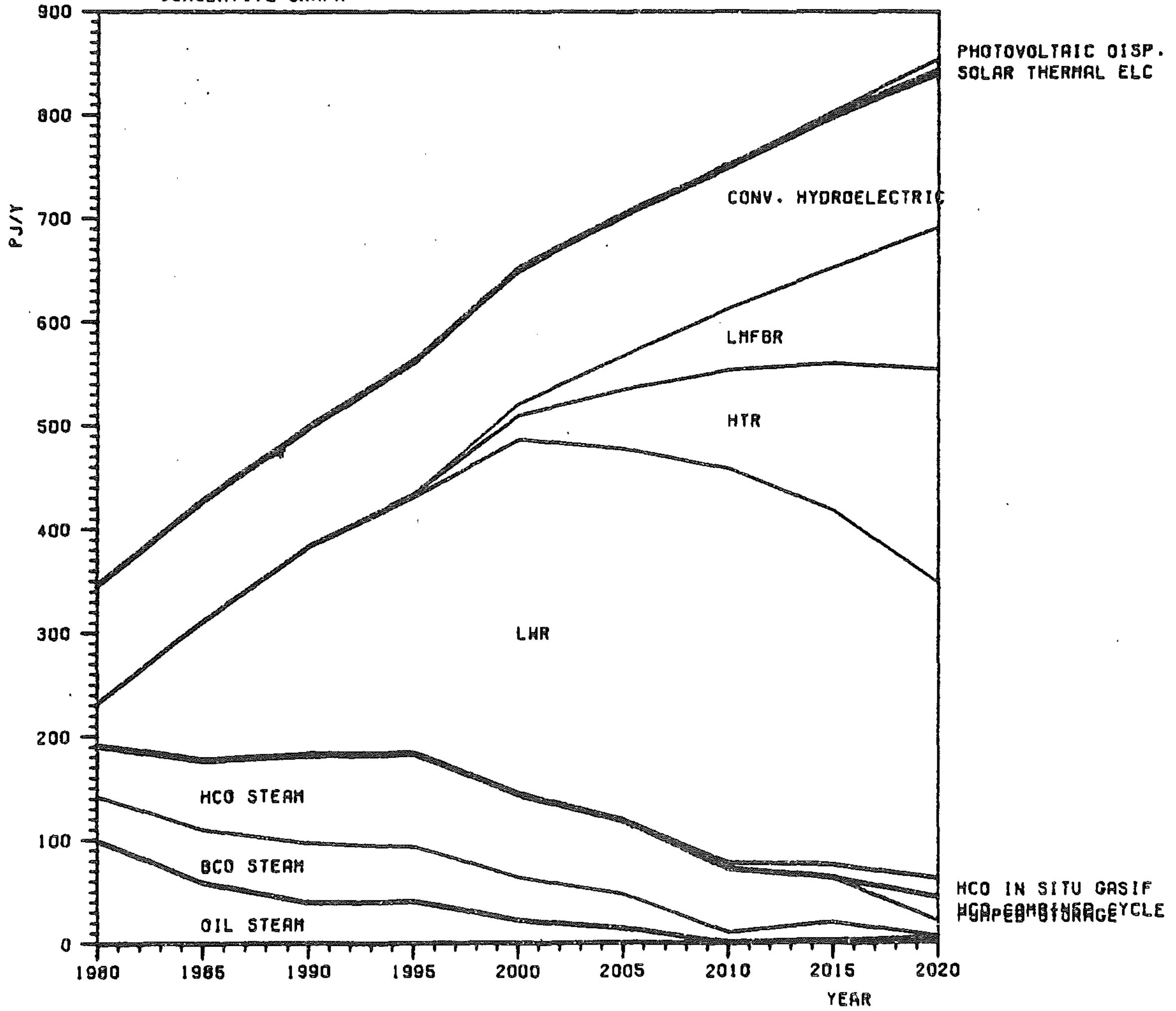


SINGLE SCENARIO FOR SPAIN RUN TSP10M SCENARIO: PS-1 DATE: 11/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
99.0	58.8	38.9	40.3	22.1	14.1	0.0	1.8	4.2	1	- OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	- FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	- FOSSIL COGENERATION
42.5	50.8	57.3	53.0	41.5	33.2	10.1	18.2	1.7	4	- BCO STEAM
49.1	67.1	85.5	90.0	80.2	70.4	61.0	43.0	14.4	5	- HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.7	6	- HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	- HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	- HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	0.0	0.0	6.2	12.3	18.5	9	- HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	A	- GAS FUEL CELL
41.3	134.3	201.4	247.2	342.7	359.3	380.6	342.0	285.5	B	- LWR
0.0	0.0	0.0	3.2	23.2	57.8	95.6	142.6	206.6	C	- HTR
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	D	- LMFBR
114.1	116.9	115.7	128.8	131.8	136.9	138.4	146.3	148.1	E	- CONV. HYDROELECTRIC
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	F	- SOLAR THERMAL ELC
0.0	0.0	0.0	-0.4	-0 8	-0.9	-0.6	-0.2	-1.0	G	- PUMPED STORAGE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	H	- WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I	- GEOTHERMAL HDR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	10.7	J	- PHOTOVOLTAIC DISP.
346.0	427.9	498.8	562.1	651.8	704.1	751.2	804.0	854.4		***** T O T A L *****

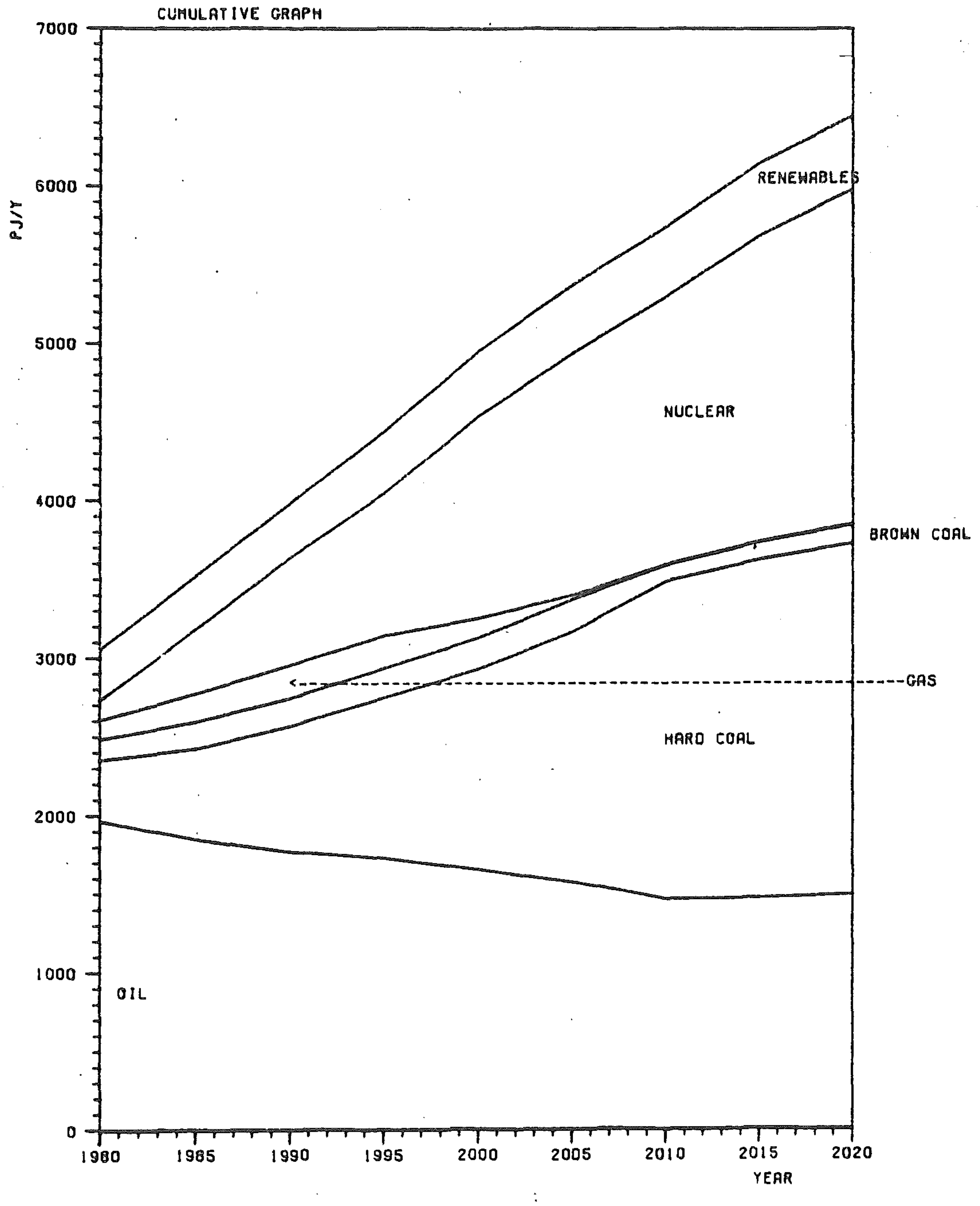
CUMULATIVE GRAPH



SINGLE SCENARIO FOR SPAIN RUN TS110X SCENARIO: SP-1(91.0/GJ) DATE: 11/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

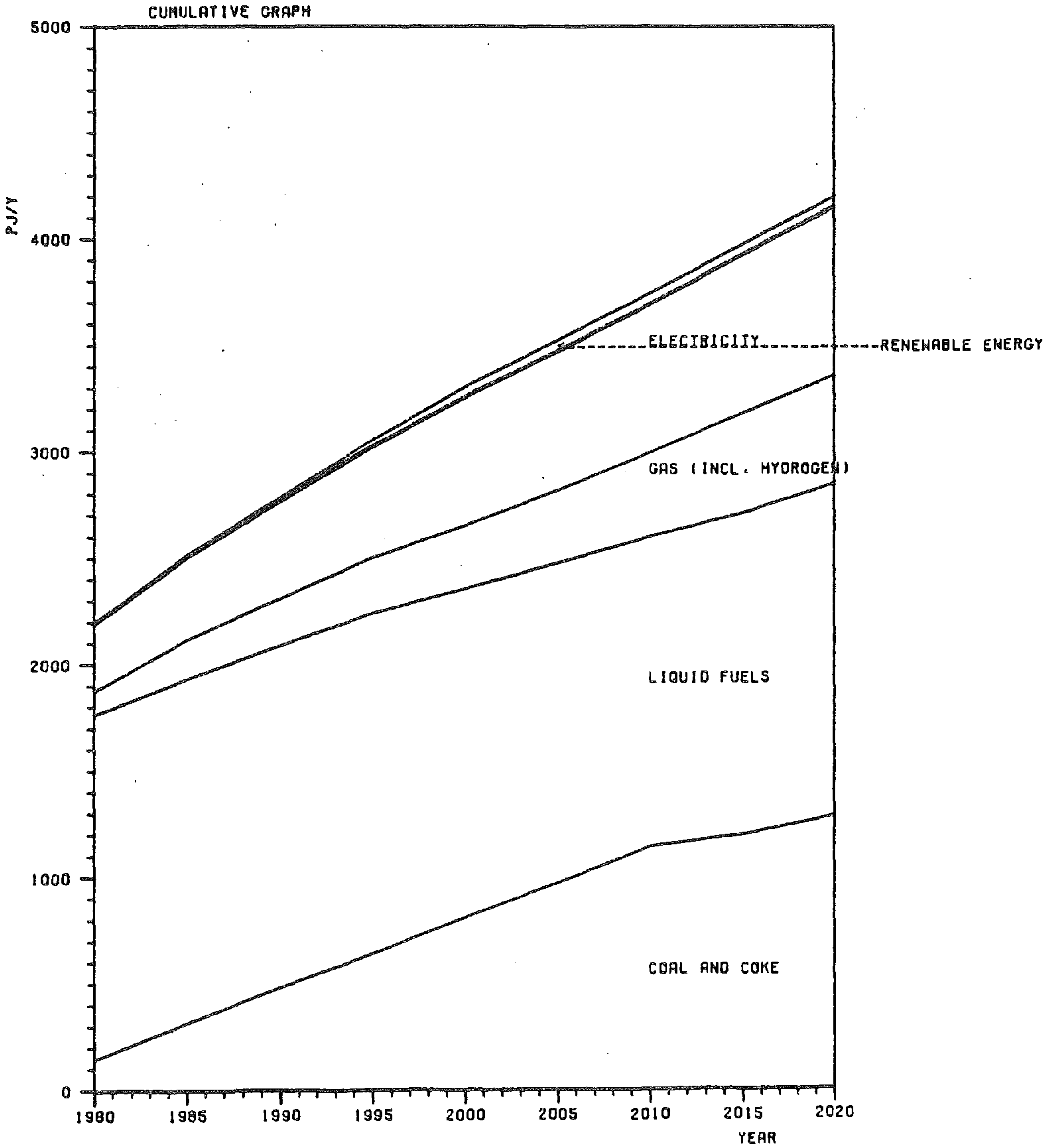
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
1969.0	1852.9	1769.9	1731.6	1654.2	1573.8	1468.2	1471.6	1492.4	1	- OIL
384.0	572.1	799.2	1017.2	1276.8	1592.3	2017.2	2152.1	2235.0	2	- HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3	- BROWN COAL
120.3	180.3	211.0	206.3	124.8	29.1	0.0	0.0	0.0	4	- GAS
124.5	404.7	682.0	904.8	1282.8	1537.4	1706.8	1945.5	2129.0	5	- NUCLEAR
326.0	340.8	347.8	392.2	414.4	435.7	443.7	461.4	467.2	6	- RENEWABLES
3055.2	3520.8	3985.9	4438.4	4949.6	5372.4	5741.5	6143.8	6444.3	*****	T O T A L *****



SINGLE SCENARIO FOR SPAIN RUN TS110X SCENARIO: SP-1(31.0/GJ) DATE: 11/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
148.4	318.4	485.3	643.5	813.8	971.7	1141.4	1196.8	1281.8	1 - COAL AND COKE
1614.5	1612.3	1607.7	1597.8	1544.5	1504.5	1457.2	1511.6	1565.0	2 - LIQUID FUELS
110.2	186.3	220.9	263.1	295.6	342.5	396.0	471.2	507.6	3 - GAS (INCL. HYDROGEN)
320.8	390.9	460.7	522.0	605.7	654.2	698.9	748.5	796.7	4 - ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5 - PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6 - DISTRICT HEAT
0.0	6.9	17.4	31.4	45.4	51.6	49.2	46.8	47.5	7 - RENEWABLE ENERGY
2193.9	2514.8	2792.0	3057.8	3305.0	3524.5	3742.7	3974.9	4198.6	***** T O T A L *****

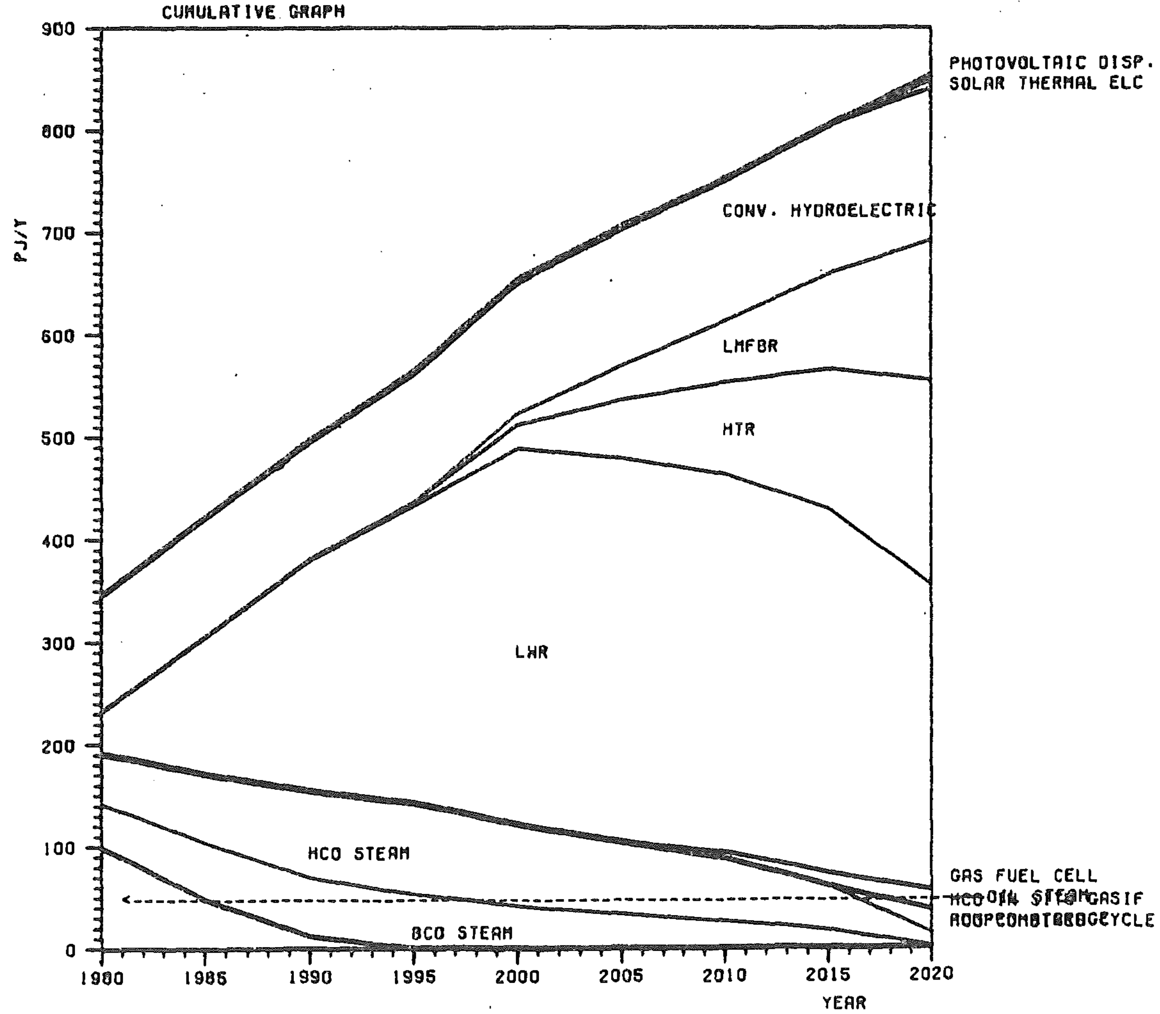


SINGLE SCENARIO FOR SPAIN RUN TS110X SCENARIO: SP-1($1.0/GJ) DATE: 11/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
99.0	48.1	11.6	0.0	0.0	0.0	0.0	0.0	0.0	1 - OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2 - FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3 - FOSSIL COGENERATION
42.5	55.3	57.3	52.9	41.5	33.2	26.3	17.7	1.7	4 - BCO STEAM
49.1	67.1	86.4	89.3	79.6	70.5	61.1	43.0	12.4	5 - HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.7	6 - HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7 - HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8 - HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	0.0	0.0	6.2	12.3	18.5	9 - HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	A - GAS FUEL CELL
41.3	134.3	226.3	290.5	367.3	374.8	369.2	355.9	297.3	B - LWR
0.0	0.0	0.0	3.2	23.2	57.8	90.2	136.8	200.8	C - HTR
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	D - LMFBR
114.1	116.9	115.7	128.8	131.8	136.9	138.3	146.4	148.3	E - CONV. HYDROELECTRIC
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	F - SOLAR THERMAL ELC
0.0	0.0	0.0	-2.5	-2.6	-2.4	-0.3	-1.3	-1.3	G - PUMPED STORAGE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	H - WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I - GEOTHERMAL HDR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	J - PHOTOVOLTAIC DISP.
346.0	421.7	498.3	562.2	651.9	704.1	750.9	803.9	854.8	===== T O T A L =====

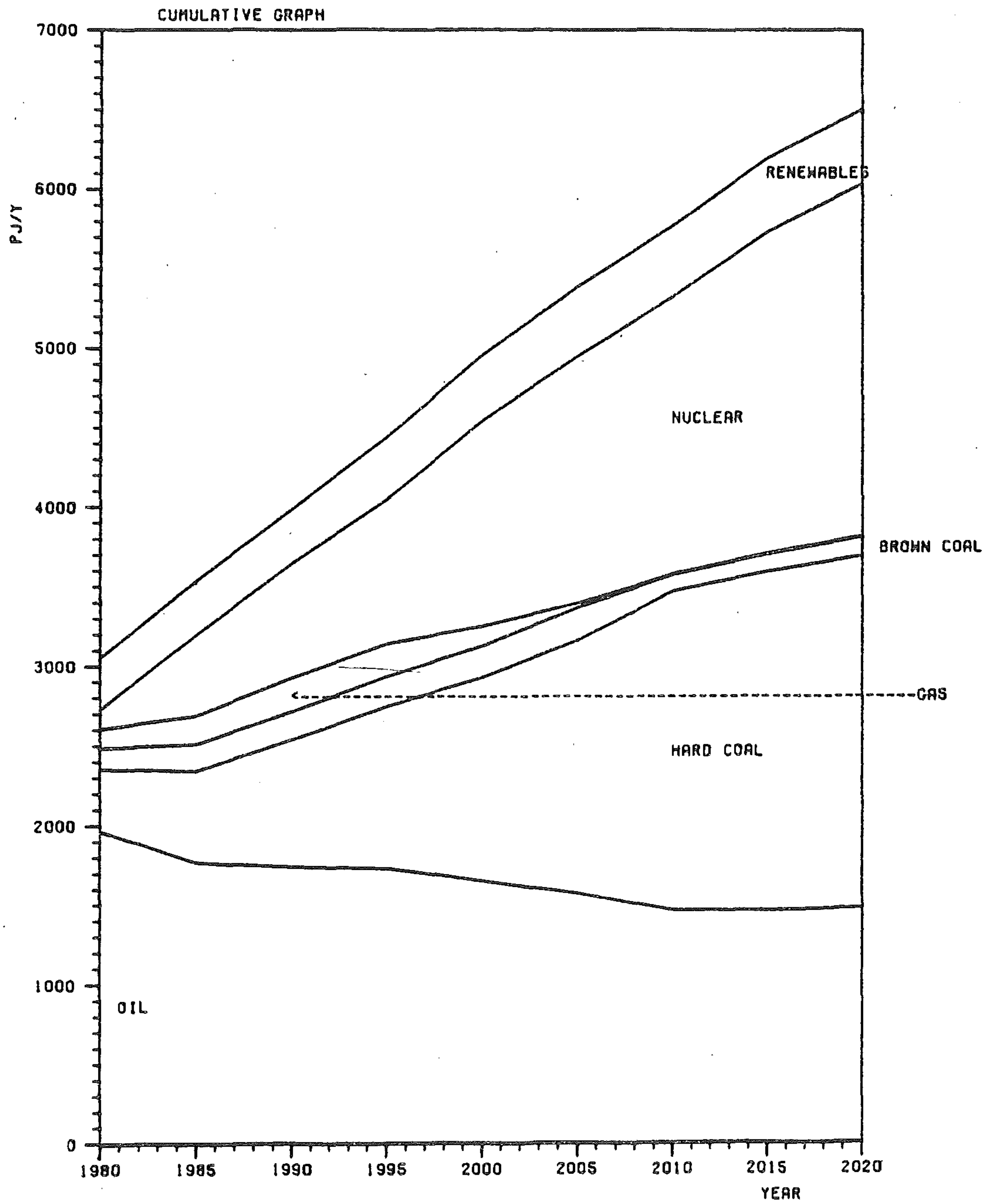
CUMULATIVE GRAPH



SINGLE SCENARIO FOR SPAIN RUN TSSION SCENARIO: SP-1 DATE: 11/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

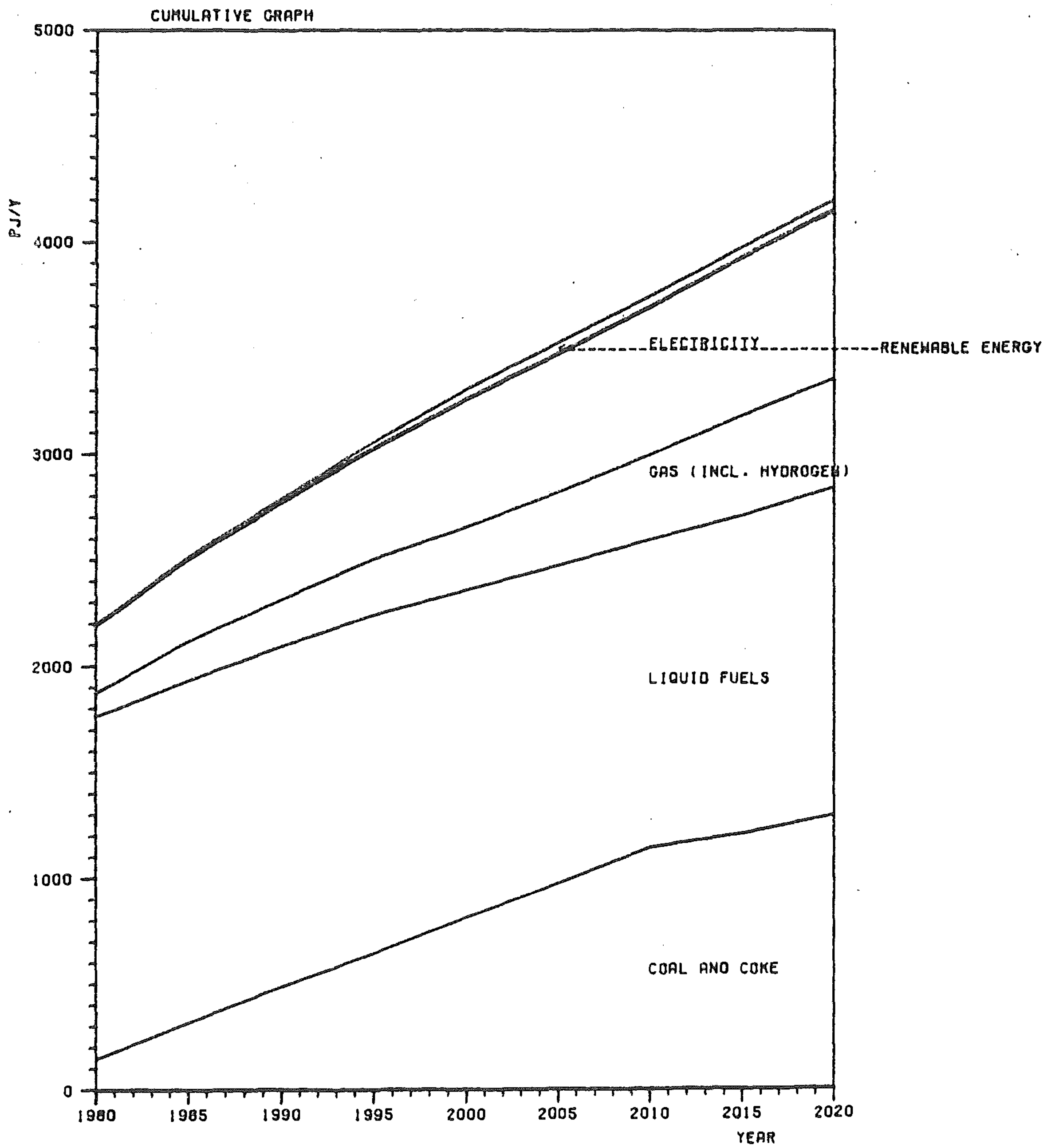
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1769.0	1740.3	1731.3	1652.6	1570.6	1463.0	1462.3	1476.8	1 - OIL
384.0	572.1	799.6	1017.5	1278.1	1592.4	2006.7	2130.1	2215.0	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3 - BROWN COAL
120.3	180.3	211.0	206.3	124.8	29.1	0.0	0.0	0.0	4 - GAS
124.8	506.0	720.5	906.3	1290.5	1554.8	1749.3	2024.3	2220.4	5 - NUCLEAR
326.0	338.7	344.0	392.3	414.9	437.2	444.7	463.4	468.8	6 - RENEWABLES
3055.5	3536.1	3991.4	4440.0	4957.5	5388.2	5769.3	6193.3	6501.7	===== T O T A L =====



SINGLE SCENARIO FOR SPAIN | RUN TSS10M | SCENARIO: SP-1 | DATE: 11/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

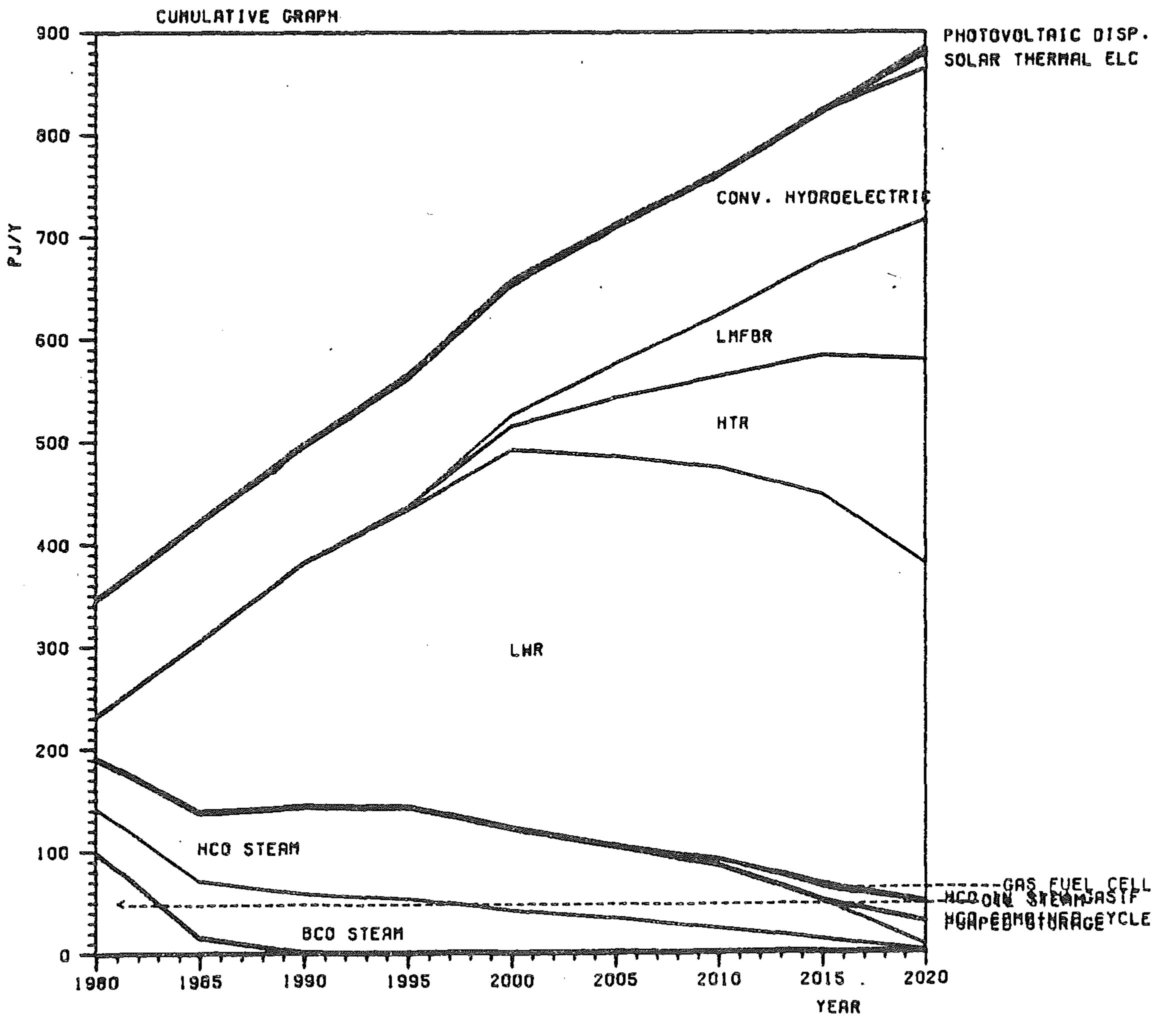
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
148.4	318.4	485.3	643.5	813.8	971.7	1141.4	1204.7	1289.7	1 - COAL AND COKE
1614.5	1612.3	1607.7	1597.5	1543.0	1501.5	1452.2	1502.6	1550.0	2 - LIQUID FUELS
110.2	186.3	220.9	263.4	297.1	345.5	401.0	472.2	514.6	3 - GAS (INCL. HYDROGEN)
320.8	390.9	460.7	522.0	605.7	654.2	698.9	748.5	796.7	4 - ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5 - PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6 - DISTRICT HEAT
0.0	6.9	17.4	31.4	45.4	51.6	49.2	46.8	47.5	7 - RENEWABLE ENERGY
2193.9	2514.8	2792.0	3057.8	3305.0	3524.5	3742.7	3974.8	4198.5	***** T O T A L *****



SINGLE SCENARIO FOR SPAIN RUN TSSIOM SCENARIO: SP-1 DATE: 11/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

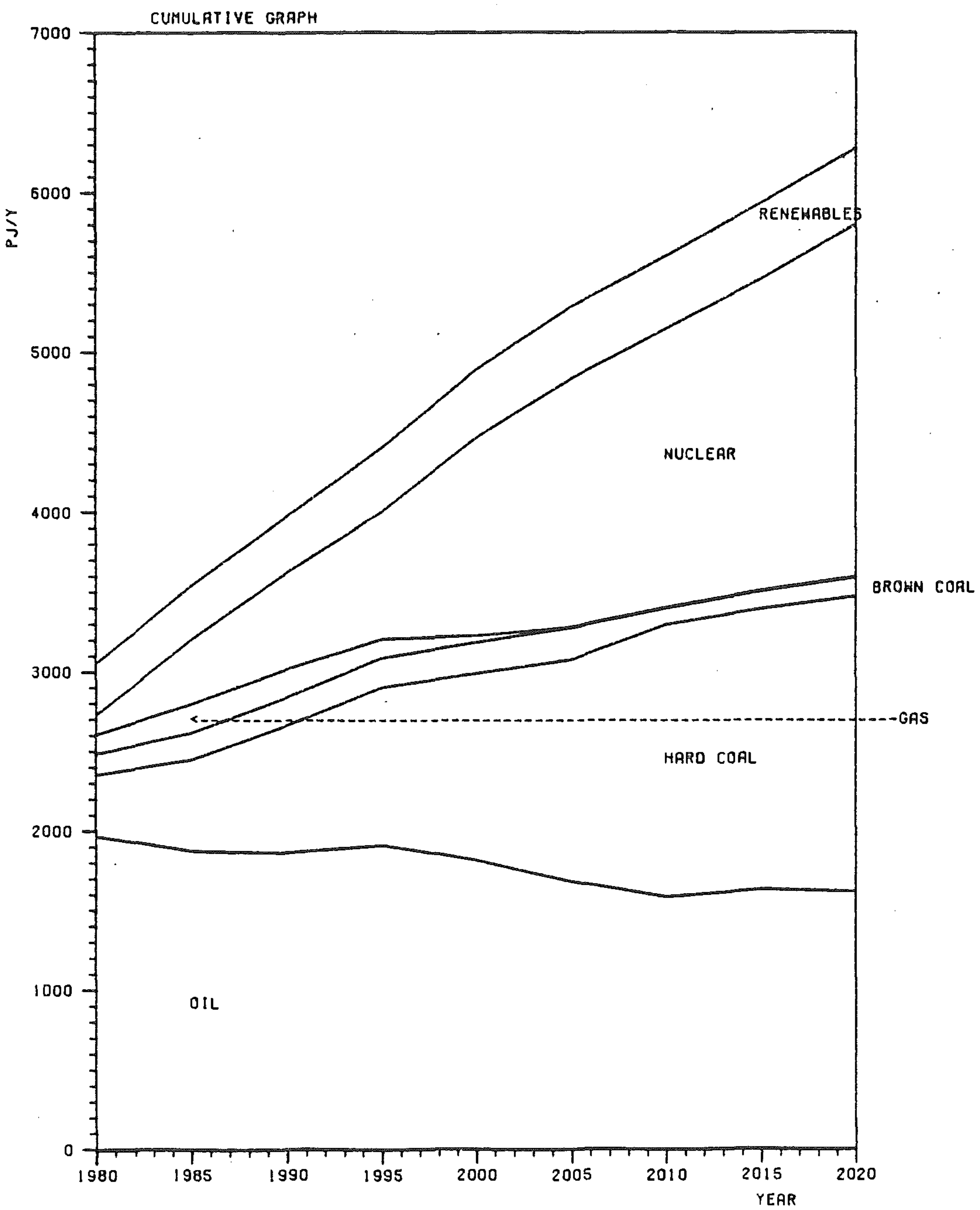
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
99.0	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1	OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	FOSSIL COGENERATION
42.5	55.3	57.3	52.9	41.5	33.2	23.5	12.7	1.7	4	BCO STEAM
49.1	67.1	85.5	89.4	80.0	70.5	61.1	37.8	4.9	5	HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.7	6	HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	0.0	0.0	6.2	12.3	18.5	9	HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.2	A	GAS FUEL CELL
41.4	167.9	239.0	291.0	369.9	380.6	382.8	380.1	329.0	B	LWR
0.0	0.0	0.0	3.2	23.2	57.8	89.6	136.3	200.0	C	HTR
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	D	LMFBR
114.1	116.9	115.6	128.8	131.8	136.9	138.4	146.6	148.2	E	CONV. HYDROELECTRIC
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4	F	SOLAR THERMAL ELC
0.0	-0.7	-1.3	-2.5	-2.5	-1.9	0.0	-0.7	-0.7	G	PUMPED STORAGE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	H	WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I	GEOTHERMAL HOR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	J	PHOTOVOLTAIC DISP.
346.1	421.7	496.1	562.8	655.0	710.4	761.5	822.7	886.1	*****	T O T A L *****



SINGLE SCENARIO FOR SPAIN RUN TSP4ON SCENARIO: PS-4 DATE: 8/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

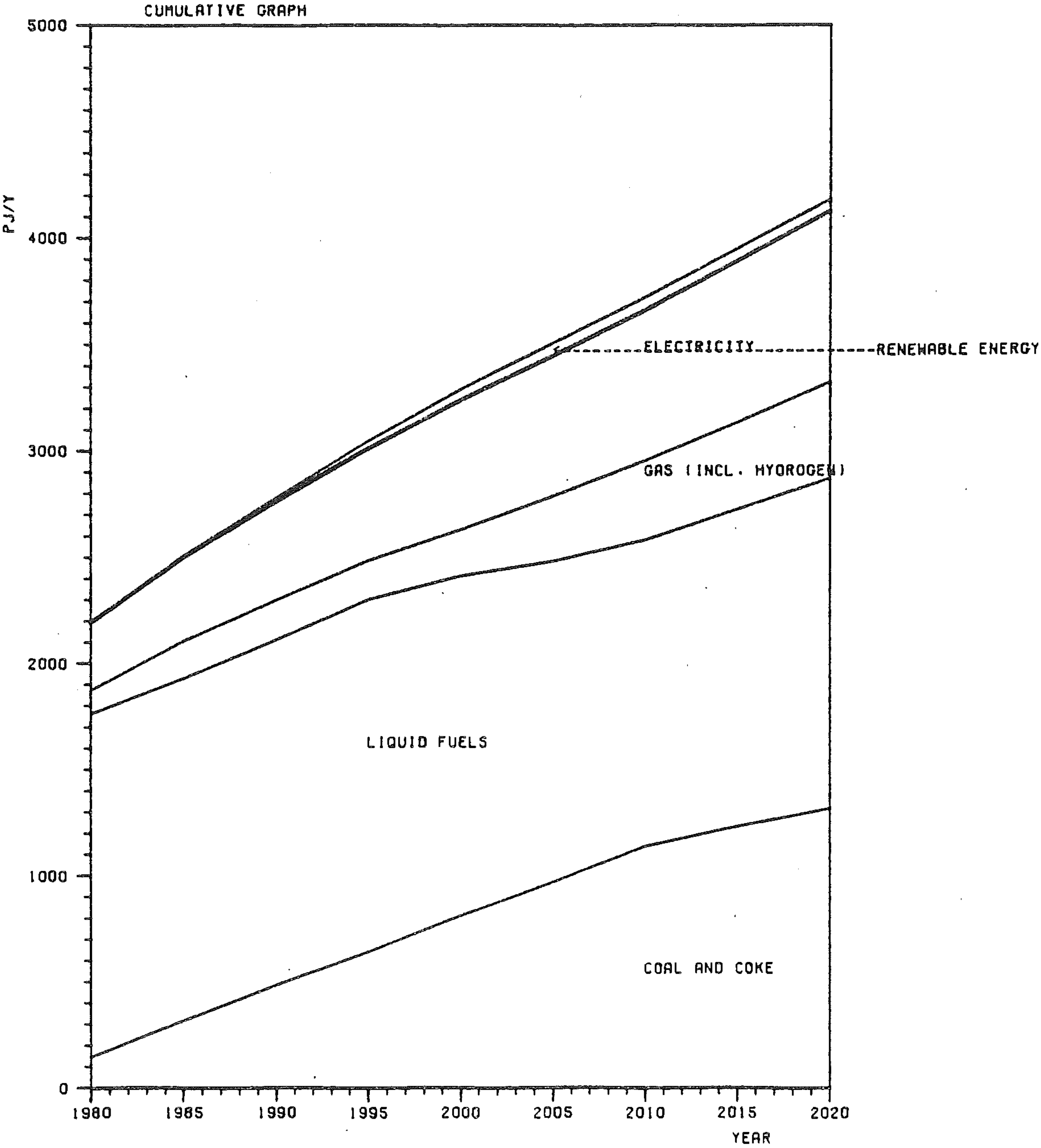
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1875.6	1864.4	1911.8	1818.5	1682.8	1588.2	1633.2	1620.6	1 - OIL
384.0	572.1	799.6	990.8	1171.2	1394.5	1708.2	1760.1	1852.4	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3 - BROWN COAL
120.3	180.3	177.5	119.0	41.9	0.0	0.0	0.0	0.0	4 - GAS
124.5	404.7	607.0	795.1	1239.1	1558.8	1746.6	1955.7	2211.4	5 - NUCLEAR
326.0	340.4	349.1	401.9	425.2	449.2	454.4	475.1	474.7	6 - RENEWABLES
3055.2	3543.1	3973.6	4404.9	4892.5	5289.4	5603.0	5937.3	6279.8	■■■■■ T O T A L ■■■■■



SINGLE SCENARIO FOR SPAIN RUN TSP40N SCENARIO: PS-4 DATE: 8/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

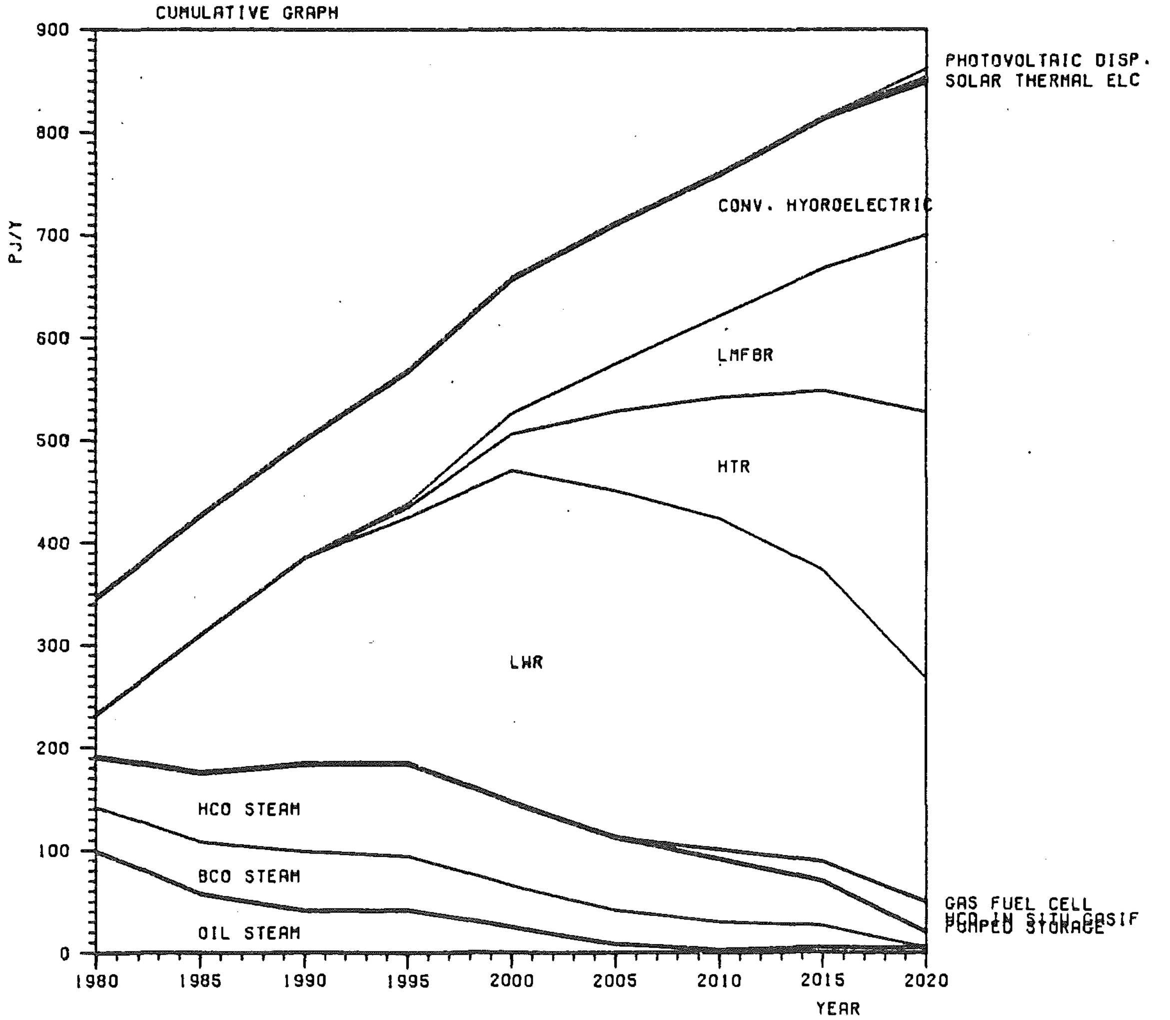
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
148.4	318.4	485.3	643.5	813.8	971.7	1141.4	1232.2	1317.3	1	- COAL AND COKE
1614.5	1611.3	1627.5	1660.9	1602.0	1512.5	1442.2	1495.6	1555.9	2	- LIQUID FUELS
110.2	175.7	189.1	183.4	217.7	306.4	374.7	408.8	453.1	3	- GAS (INCL. HYDROGEN)
320.8	395.4	465.3	527.1	611.0	660.9	707.8	758.9	803.9	4	- ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	- PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	- DISTRICT HEAT
0.0	6.5	18.6	34.4	50.3	60.0	59.6	59.2	54.8	7	- RENEWABLE ENERGY
2193.9	2507.3	2785.8	3049.3	3294.8	3511.5	3725.7	3954.7	4185.0		***** T O T A L *****



SINGLE SCENARIO FOR SPAIN RUN TSP40N SCENARIO: PS-4 DATE: 8/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

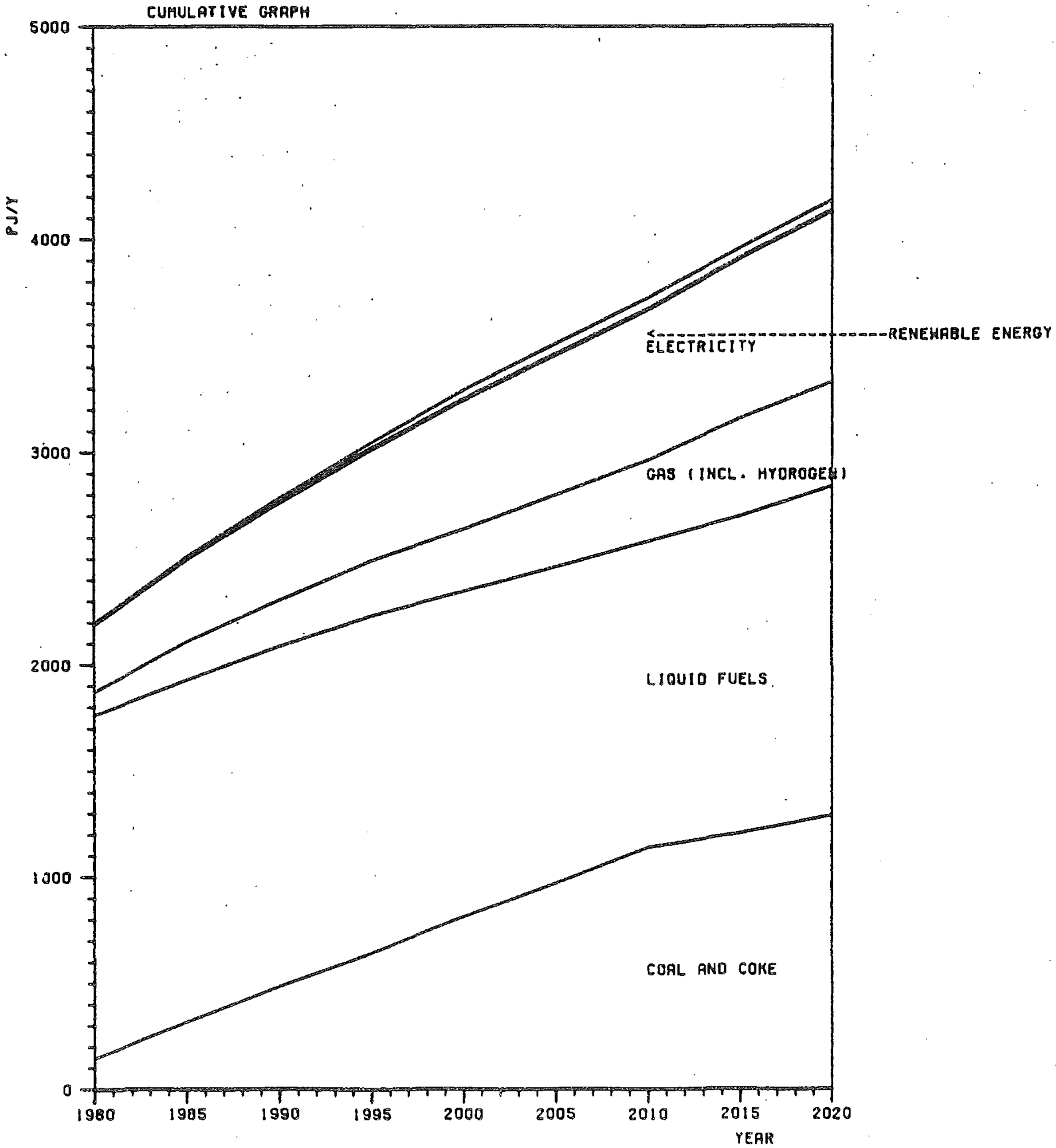
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
99.0	57.3	41.1	41.8	24.6	8.3	2.9	4.9	4.9	1	- OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	- FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	- FOSSIL COGENERATION
42.5	50.8	57.3	53.0	40.9	33.2	27.3	21.4	0.0	4	- BCO STEAM
49.1	67.1	86.6	90.0	80.9	70.4	61.1	42.9	14.9	5	- HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	- HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	- HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	- HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	0.0	0.0	9.6	19.3	28.9	9	- HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	A	- GAS FUEL CELL
41.3	134.3	201.4	240.5	323.9	338.4	322.7	284.5	217.3	B	- LWR
0.0	0.0	0.0	9.3	36.1	77.9	118.5	175.2	260.4	C	- HTR
0.0	0.0	0.0	4.4	20.0	46.6	79.8	119.7	172.9	D	- LMFBR
114.1	116.9	115.7	128.8	131.8	136.9	138.2	146.1	147.9	E	- CONV. HYDROELECTRIC
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	F	- SOLAR THERMAL ELC
0.0	0.0	0.0	-0.2	-0.6	-0.7	0.0	-0.6	-1.0	G	- PUMPED STORAGE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	H	- WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I	- GEOTHERMAL HDR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	9.0	J	- PHOTOVOLTAIC DISP.
346.0	426.4	501.1	567.6	657.6	711.0	760.1	814.6	861.9	=====	T O T A L =====



SINGLE SCENARIO FOR SPAIN RUN TS410X SCENARIO: SP-4(31.0/GJ) DATE: 11/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

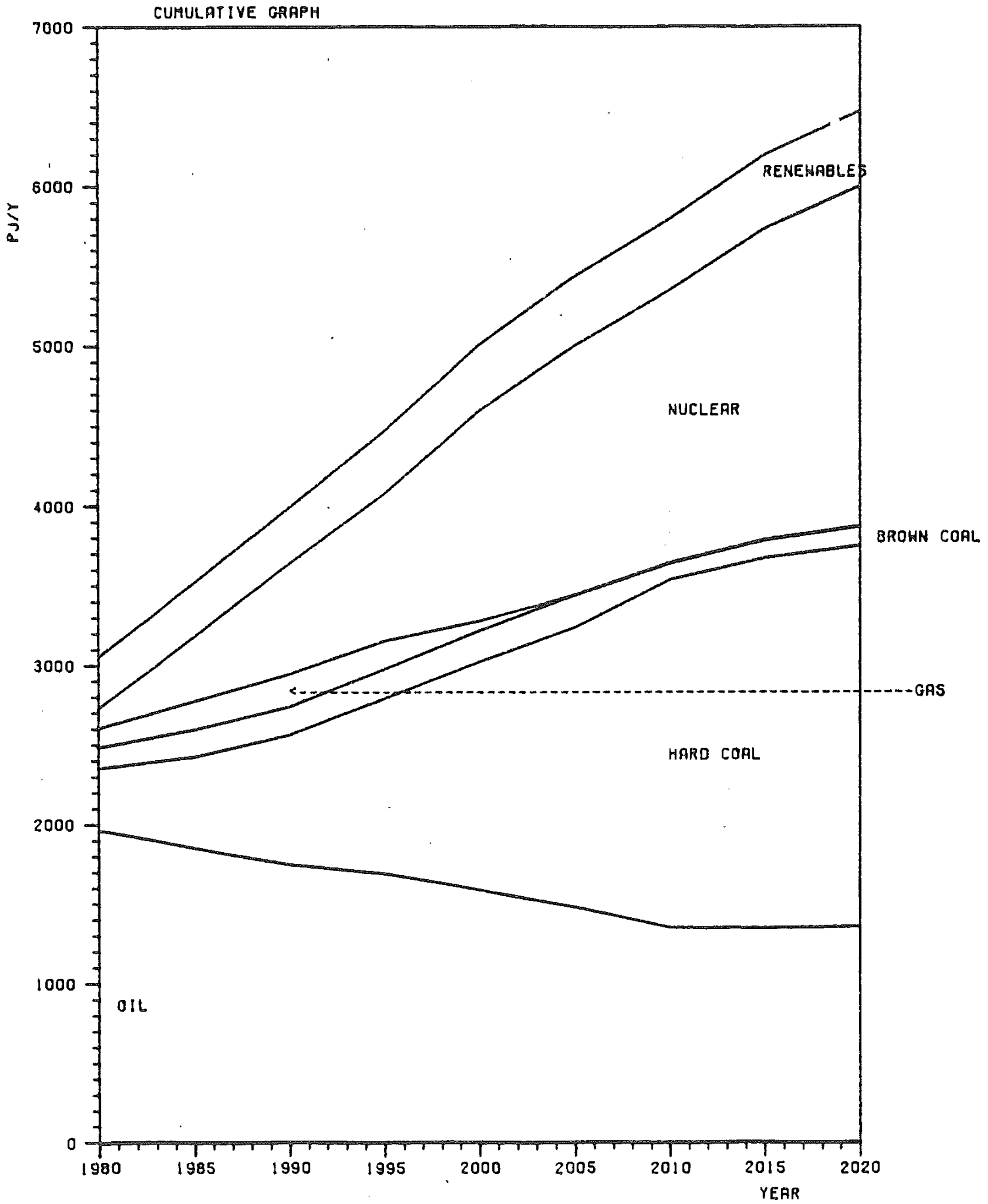
980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
148.4	318.4	485.3	643.5	813.8	971.7	1141.4	1207.6	1292.6	1	- COAL AND COKE
1614.5	1611.3	1603.5	1589.3	1533.9	1492.0	1442.2	1495.6	1550.0	2	- LIQUID FUELS
110.2	179.8	218.7	261.1	293.5	338.6	382.8	459.2	490.5	3	- GAS (INCL. HYDROGEN)
320.8	392.2	462.4	525.9	611.0	660.9	707.8	755.0	803.8	4	- ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	- PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	- DISTRICT HEAT
0.0	8.3	18.6	31.2	43.6	49.9	52.7	46.1	49.2	7	- RENEWABLE ENERGY
2193.9	2510.0	2788.5	3051.0	3295.8	3513.1	3726.9	3963.5	4186.1		===== T O T A L =====



SINGLE SCENARIO FOR SPAIN RUN TS410X SCENARIO: SP-4($1.0/GJ) DATE: 11/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

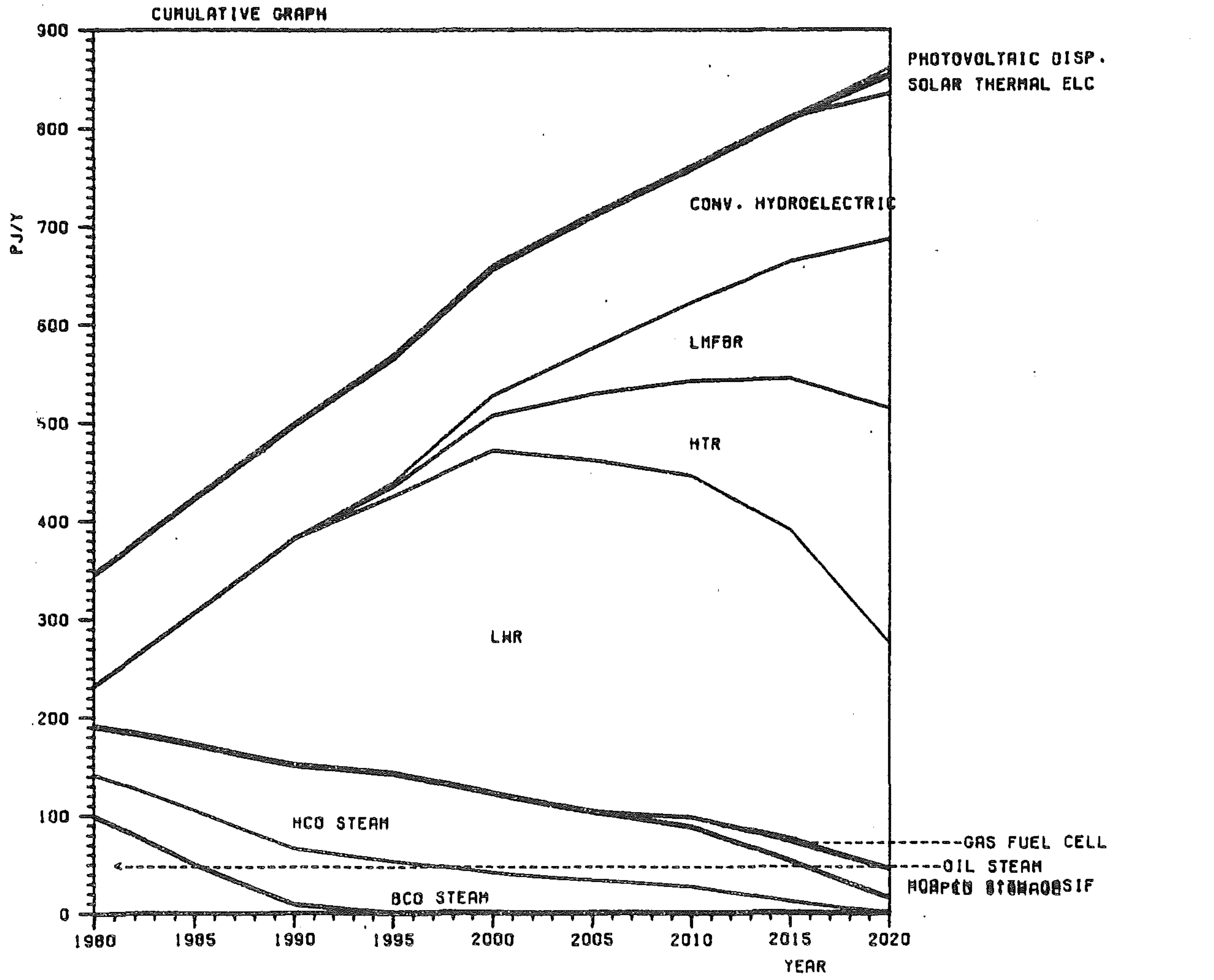
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1855.3	1748.4	1692.6	1589.9	1480.0	1354.6	1347.1	1358.3	1 - OIL
384.0	572.1	818.8	1101.9	1435.1	1761.4	2184.6	2326.7	2392.0	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3 - BROWN COAL
120.3	180.3	205.0	174.9	59.9	0.0	0.0	0.0	0.0	4 - GAS
124.5	404.7	697.5	923.2	1317.9	1561.6	1708.1	1950.4	2132.2	5 - NUCLEAR
326.0	342.2	349.1	393.5	414.5	436.4	444.9	462.0	468.4	6 - RENEWABLES
3055.2	3524.6	3994.8	4472.4	5013.9	5443.5	5797.8	6199.4	6471.6	■■■■■ T O T A L ■■■■■



SINGLE SCENARIO FOR SPAIN   RUN TS410X   SCENARIO: SP-4(81.0/GJ)   DATE: 11/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

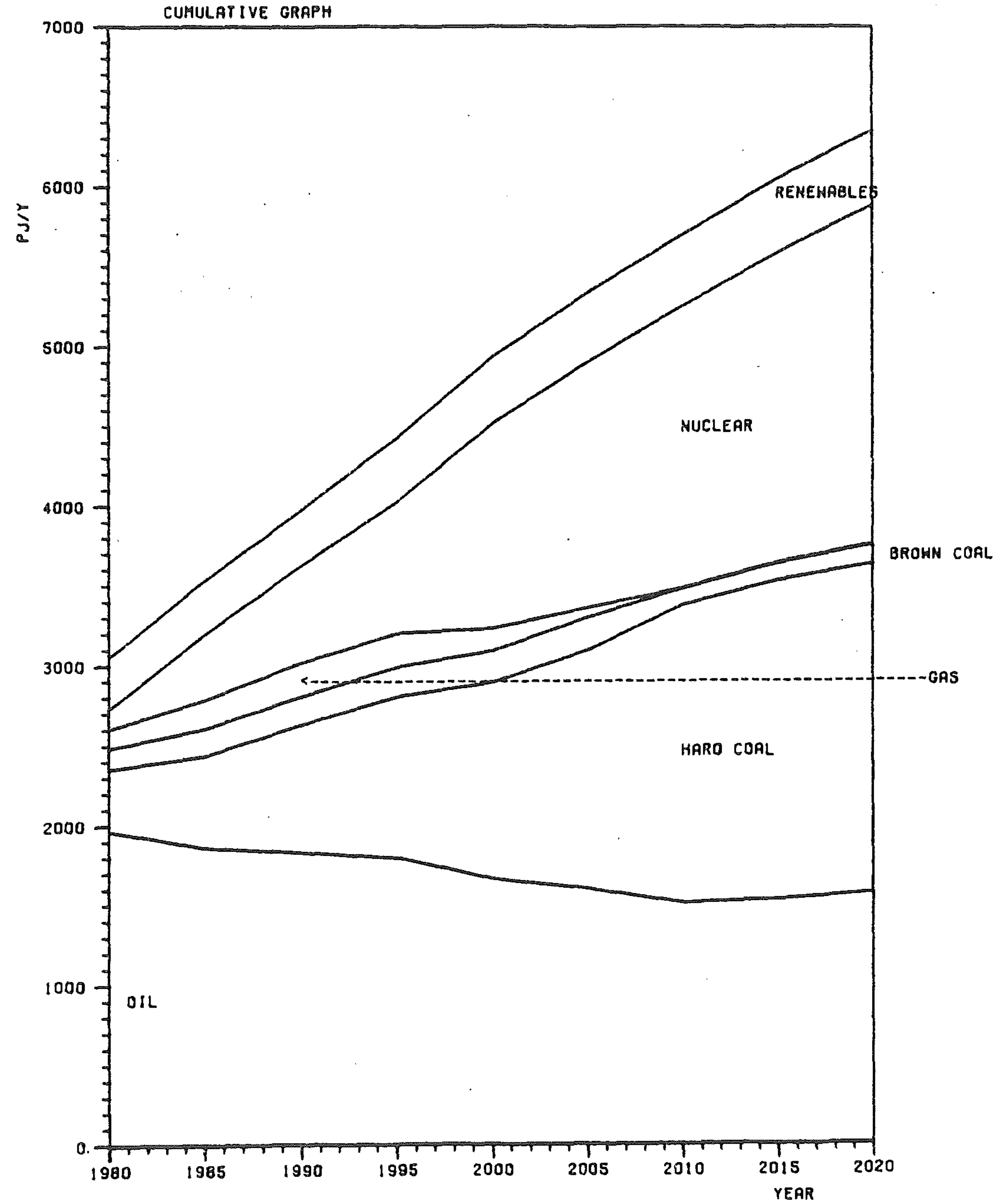
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
99.0	49.4	8.2	0.0	0.0	0.0	0.0	0.0	0.0	1	OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	FOSSIL COGENERATION
42.5	55.3	57.3	52.8	40.9	33.2	27.0	11.4	0.0	4	BCO STEAM
49.1	67.1	85.4	90.0	80.8	70.1	61.0	40.9	14.9	5	HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	0.0	0.0	9.6	19.3	28.9	9	HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.1	A	GAS FUEL CELL
41.3	134.3	231.4	283.0	350.0	358.7	348.2	314.4	229.5	B	LWR
0.0	0.0	0.0	9.3	36.1	67.3	97.3	154.6	239.2	C	HTR
0.0	0.0	0.0	4.4	20.0	46.6	79.8	119.7	172.9	D	LMFBR
114.1	116.9	115.7	128.6	131.8	136.8	138.4	146.4	148.0	E	CONV. HYDROELECTRIC
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.9	F	SOLAR THERMAL ELC
0.0	0.0	0.0	-2.0	-2.0	-1.5	-1.2	-0.9	-1.3	G	PUMPED STORAGE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	H	WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I	GEOTHERMAL HDR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	J	PHOTOVOLTAIC DISP.
346.0	423.0	498.0	566.3	657.6	711.2	760.1	810.3	861.9	*****	T O T A L *****



SINGLE SCENARIO FOR SPAIN RUN TSPICM SCENARIO: PS-1/OIL C DATE: 11/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

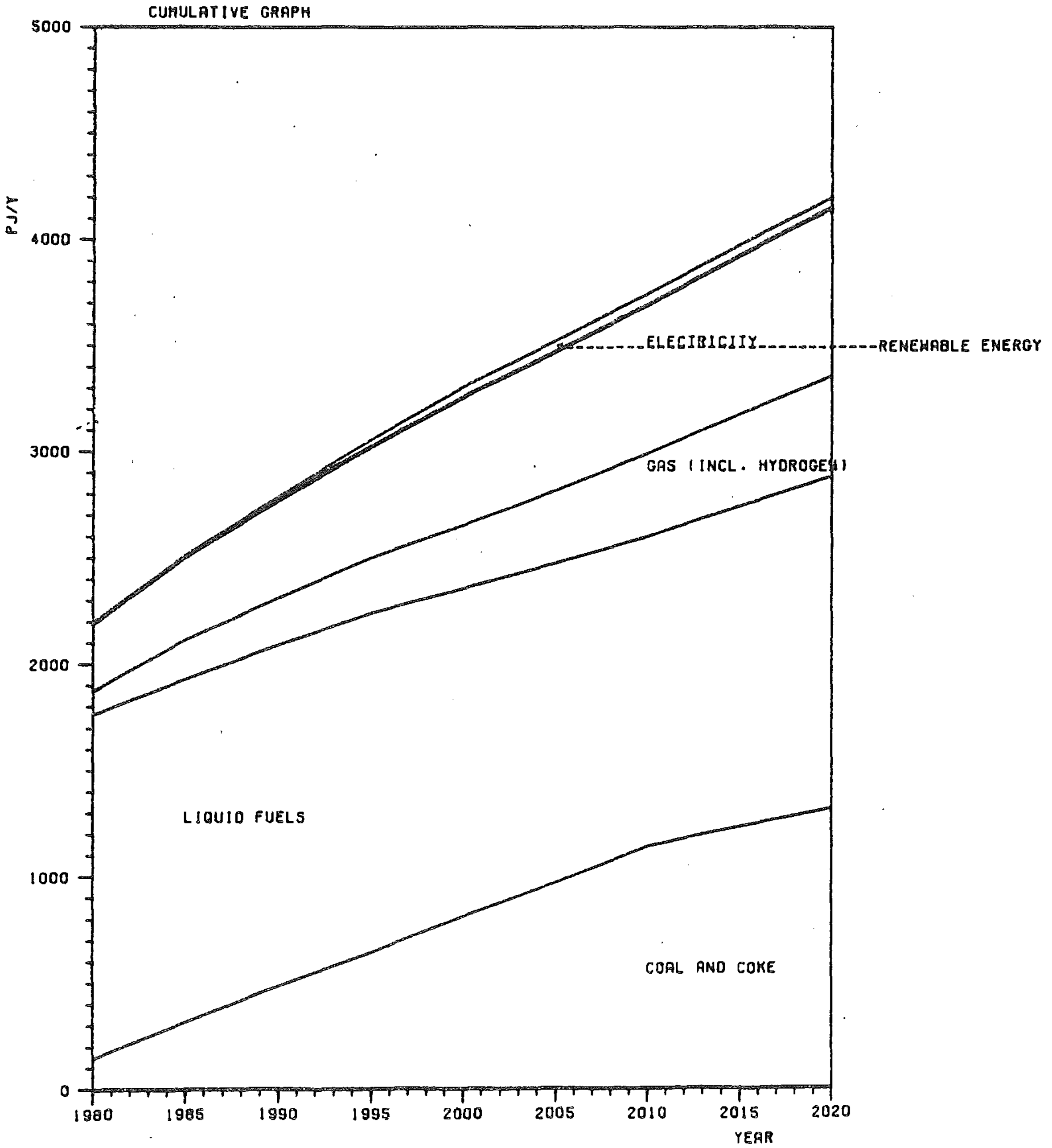
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1866.3	1833.0	1798.8	1666.8	1600.1	1512.7	1531.1	1571.7	1 - OIL
384.0	572.1	799.5	1006.4	1230.0	1494.6	1864.1	1995.5	2062.4	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3 - BROWN COAL
120.3	180.3	211.0	209.7	139.9	60.7	0.0	0.0	0.0	4 - GAS
124.5	404.7	607.0	821.0	1282.8	1537.5	1765.1	1940.7	2126.1	5 - NUCLEAR
326.0	338.9	347.8	399.4	414.4	435.7	446.2	464.9	467.8	6 - RENEWABLES
3055.2	3532.3	3974.3	4421.6	4930.5	5332.7	5693.7	6046.4	6348.7	***** T O T A L *****



SINGLE SCENARIO FOR SPAIN RUN TSPICH SCENARIO: PS-I/OIL C DATE: 11/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

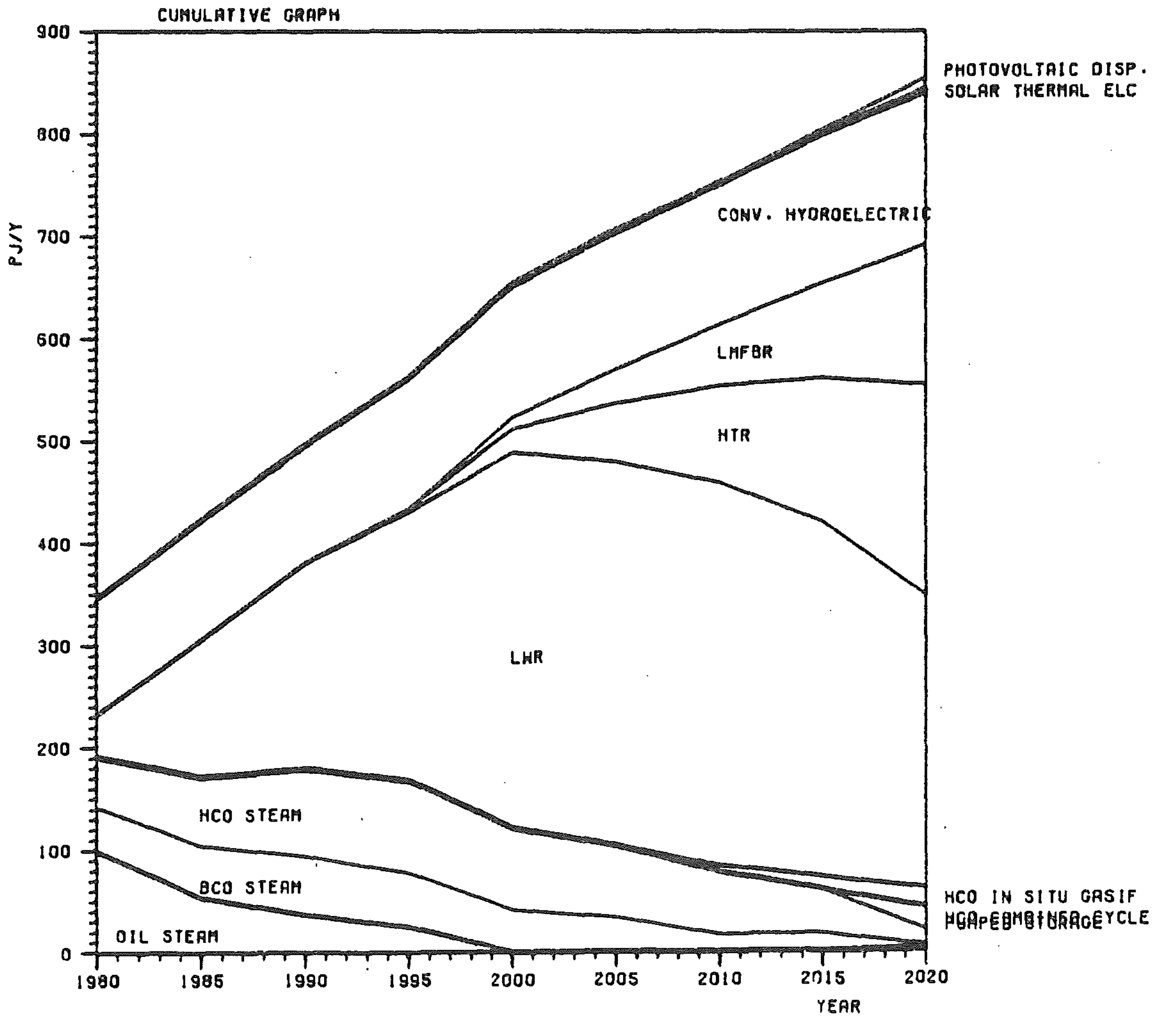
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
140.4	318.4	485.3	643.5	813.8	971.7	1141.4	1232.2	1317.3	1	- COAL AND COKE
1614.5	1612.3	1607.7	1597.8	1544.5	1504.5	1457.2	1511.6	1566.0	2	- LIQUID FUELS
110.2	186.1	220.9	262.5	295.6	342.5	392.8	432.4	472.1	3	- GAS (INCL. HYDROGEN)
320.8	391.6	460.7	522.3	605.7	654.2	699.2	748.9	796.7	4	- ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	- PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	- DISTRICT HEAT
0.0	5.0	17.4	31.4	45.4	51.6	51.5	49.1	47.5	7	- RENEWABLE ENERGY
2193.9	2513.4	2792.0	3057.5	3305.0	3524.5	3742.1	3974.2	4198.6		===== T O T A L =====



SINGLE SCENARIO FOR SPAIN RUN TSPICH SCENARIO: PS-1/OIL C DATE: 11/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

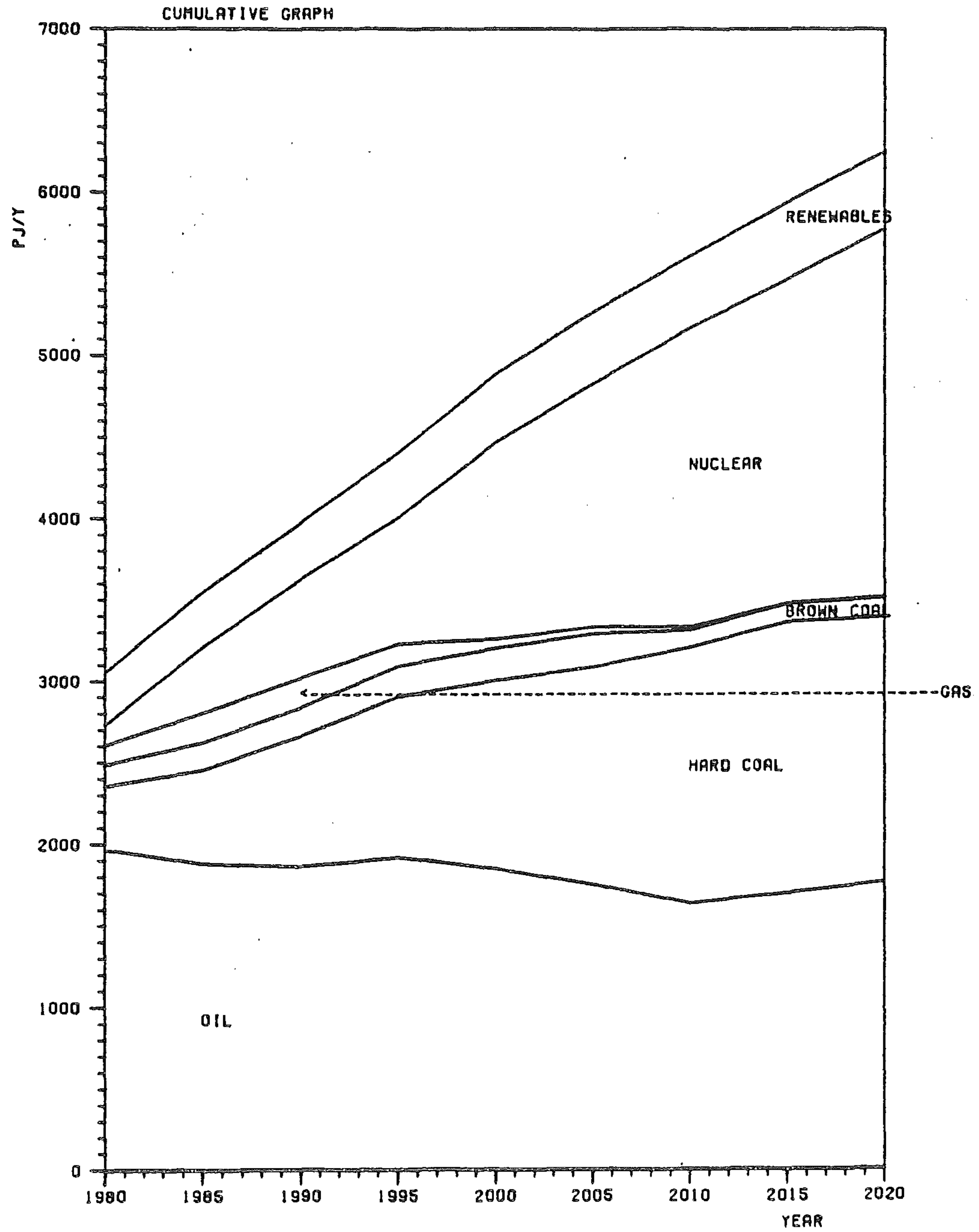
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
99.0	53.3	36.3	24.9	0.0	0.0	0.0	0.0	4.2	1 - OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2 - FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3 - FOSSIL COGENERATION
42.5	50.8	57.3	52.8	41.5	33.2	16.6	17.6	1.7	4 - BCO STEAM
49.1	67.1	85.5	90.0	79.6	70.5	61.0	42.9	14.3	5 - HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.7	6 - HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7 - HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8 - HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	0.0	0.0	6.2	12.3	18.5	9 - HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	A - GAS FUEL CELL
41.3	134.3	201.4	282.7	367.3	374.8	374.2	346.5	285.7	B - LWR
0.0	0.0	0.0	3.2	23.2	57.8	95.2	141.1	206.7	C - HTR
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	D - LMFBR
114.1	116.9	115.7	128.8	131.8	136.9	138.4	146.4	148.1	E - CONV. HYDROELECTRIC
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	F - SOLAR THERMAL ELC
0.0	0.0	0.0	0.0	-2.6	-2.4	-0.3	-0.9	-1.0	G - PUMPED STORAGE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	H - WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I - GEOTHERMAL HDR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	10.7	J - PHOTOVOLTAIC DISP.
346.0	422.4	496.2	562.4	651.9	704.1	751.2	803.9	854.4	***** T O T A L *****



SINGLE SCENARIO FOR SPAIN RUN TSP1C3 SCENARIO: PS-1/COAL C DATE: 11/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

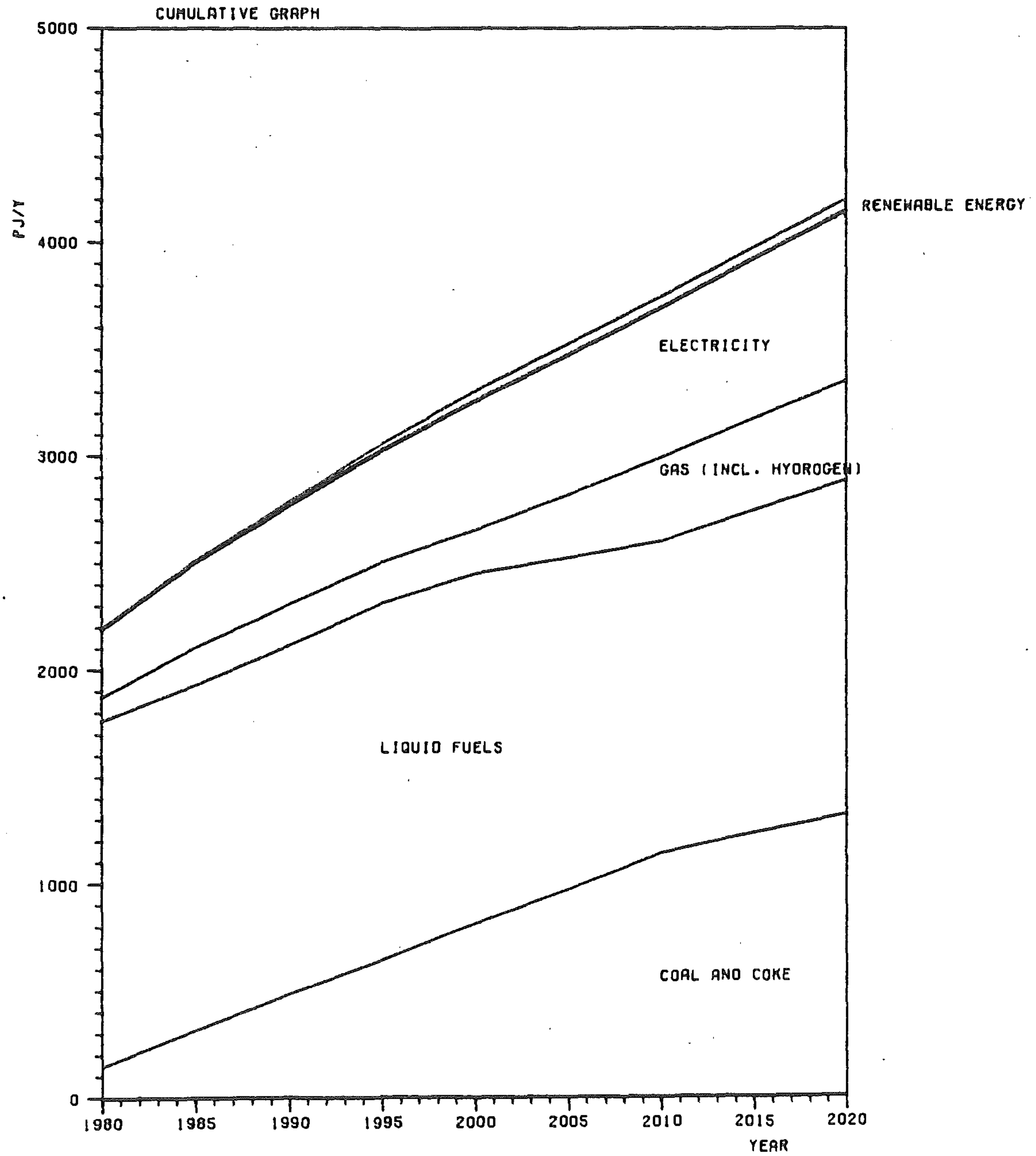
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1880.5	1863.2	1916.8	1847.6	1750.1	1632.0	1694.4	1763.5	1 - OIL
384.0	572.1	799.5	986.9	1157.1	1335.7	1572.1	1665.1	1626.0	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3 - BROWN COAL
120.3	180.3	180.7	138.9	55.4	40.7	20.6	0.0	0.0	4 - GAS
124.5	404.7	607.0	774.1	1208.6	1493.8	1833.4	1992.2	2263.7	5 - NUCLEAR
326.0	338.9	347.8	398.3	419.7	440.0	443.8	469.8	474.8	6 - RENEWABLES
3055.2	3546.5	3974.2	4401.3	4885.0	5264.4	5607.5	5934.7	6248.7	##### T O T A L #####



SINGLE SCENARIO FOR SPAIN RUN TSPIC3 SCENARIO: PS-1/COAL C DATE: 11/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
148.4	318.4	485.3	643.5	813.8	971.7	1141.4	1232.2	1317.3	1 - COAL AND COKE
1614.5	1612.3	1631.7	1669.4	1637.6	1550.0	1457.2	1511.6	1565.0	2 - LIQUID FUELS
110.2	178.1	192.2	191.5	202.5	297.0	392.7	428.6	464.7	3 - GAS (INCL. HYDROGEN)
320.8	396.8	463.2	522.0	605.7	654.2	699.2	749.3	797.6	4 - ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5 - PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6 - DISTRICT HEAT
0.0	5.0	17.4	31.4	46.4	51.6	51.6	51.6	52.4	7 - RENEWABLE ENERGY
2193.9	2510.6	2789.8	3057.8	3305.0	3524.5	3742.1	3973.3	4197.0	===== T O T A L =====

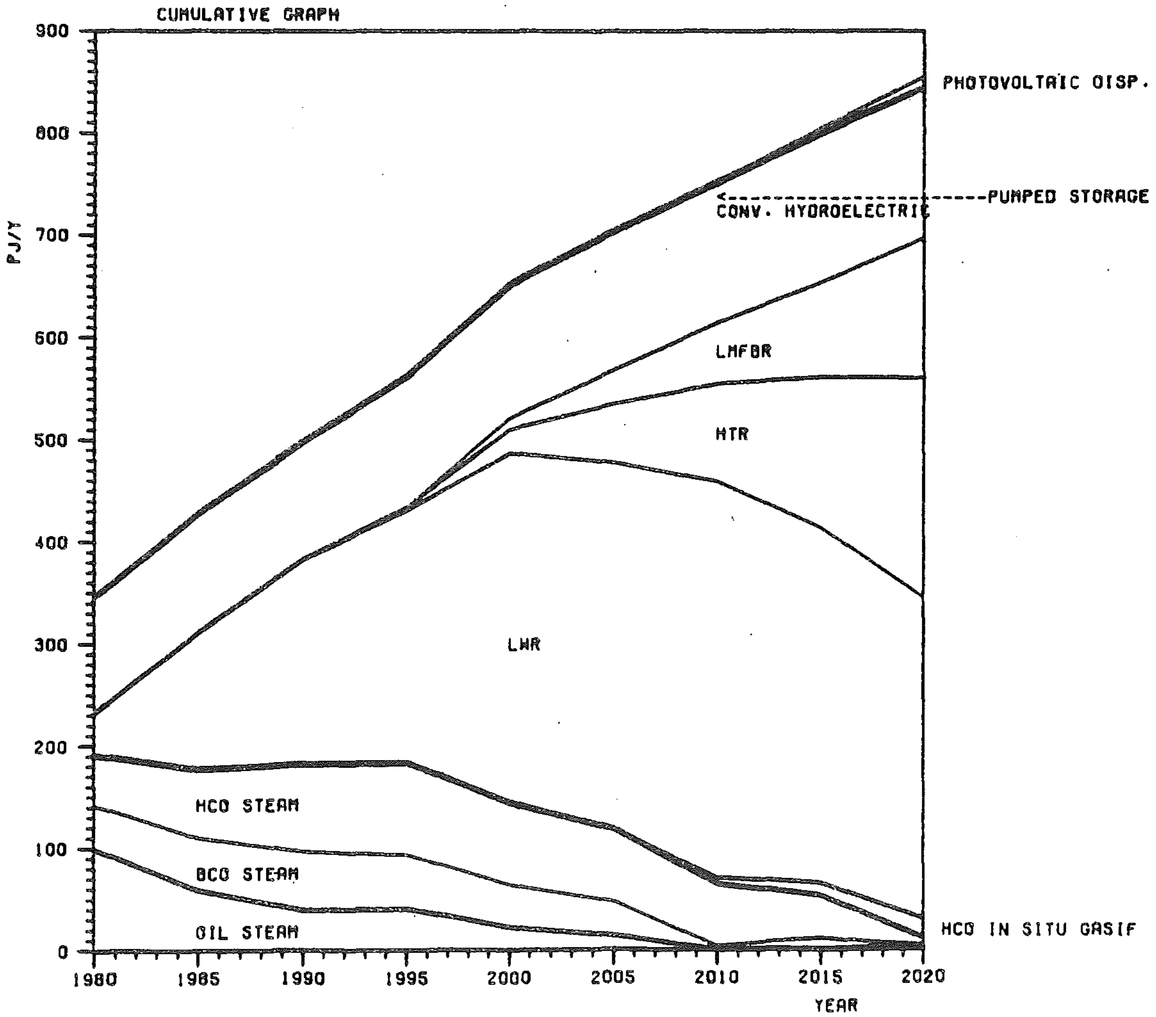


SINGLE SCENARIO FOR SPAIN   RUN TSPIC3   SCENARIO: PS-1/COAL C   DATE: 11/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
99.0	58.8	38.9	40.3	22.1	14.1	0.0	0.0	3.6	1	OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	FOSSIL COGENERATION
42.5	50.8	57.3	53.0	41.5	33.2	3.6	11.0	0.0	4	BCO STEAM
49.1	67.1	85.5	90.0	80.2	70.4	60.1	41.5	7.4	5	HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	0.0	0.0	6.2	12.3	18.5	9	HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	A	GAS FUEL CELL
41.3	134.3	201.4	247.2	342.7	359.2	388.2	347.4	314.3	B	LWR
0.0	0.0	0.0	3.2	23.2	57.9	96.0	148.0	215.6	C	HTR
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	D	LMFBR
114.1	116.9	115.7	128.8	131.8	136.9	138.4	146.4	148.2	E	CONV. HYDROELECTRIC
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	F	SOLAR THERMAL ELC
0.0	0.0	0.0	-0.4	-0.8	-0.9	-1.1	0.0	-0.3	G	PUMPED STORAGE
0.0	0.0	0.0	0.0	0 0	0.0	0.0	0.0	0.0	H	WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I	GEOTHERMAL HOR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	10.7	J	PHOTOVOLTAIC DISP.
346.0	427.9	498.8	562.1	651.8	704.1	751.3	804.6	855.4	=====	T O T A L =====

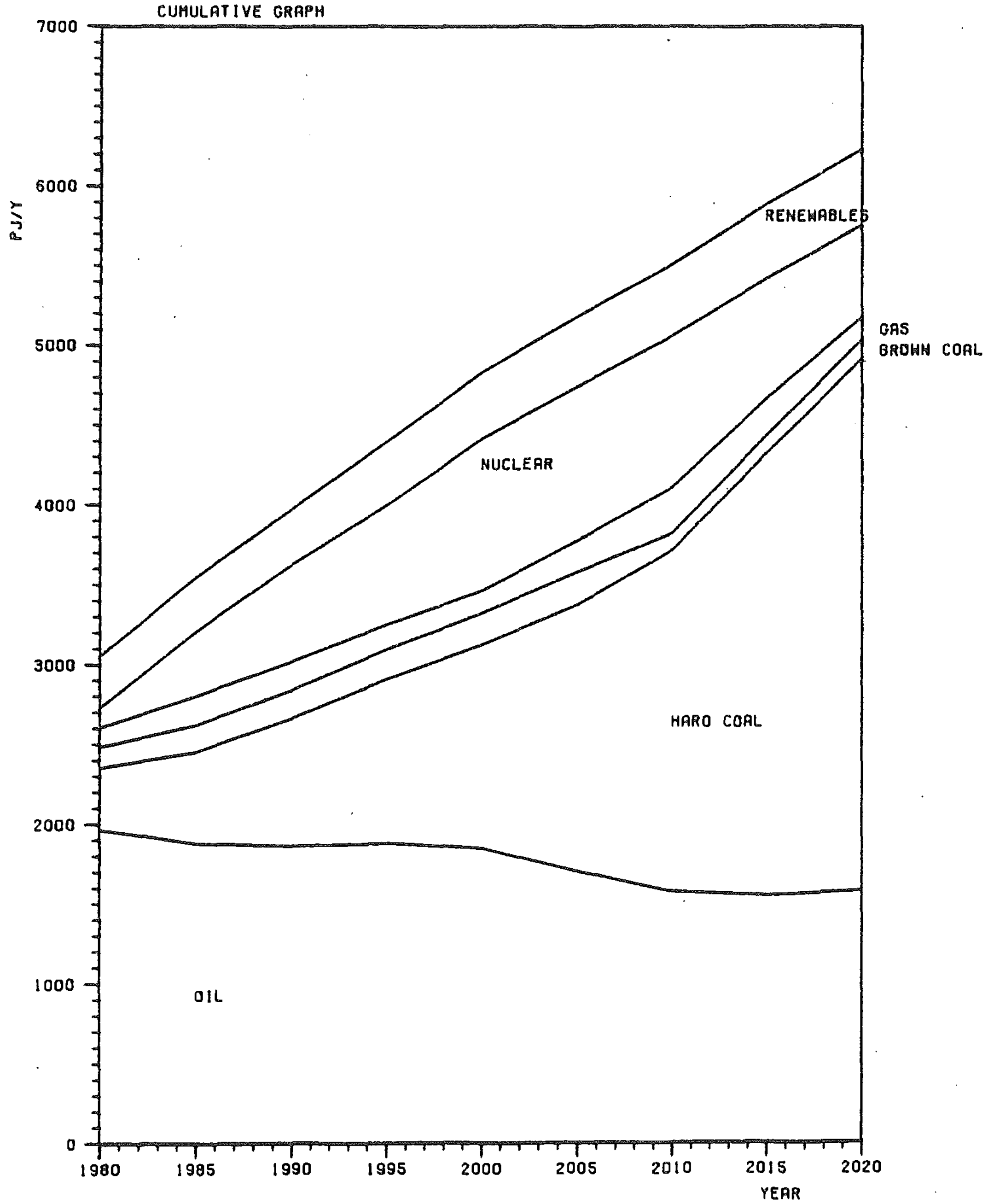
CUMULATIVE GRAPH



SINGLE SCENARIO FOR SPAIN RUN TSPINN SCENARIO: PS-1/LIM NUC DATE: 11/11/79

TABLE 2: PRIMARY ENERGY JY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1880.5	1865.3	1881.7	1849.4	1700.6	1575.8	1548.9	1578.0	1 - OIL
384.0	572.1	799.5	1028.5	1276.8	1675.6	2143.8	2773.1	3336.1	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3 - BROWN COAL
120.3	180.3	179.1	155.8	139.0	199.0	287.3	232.4	142.3	4 - GAS
124.5	404.7	607.0	745.8	953.9	965.4	948.1	751.5	578.1	5 - NUCLEAR
326.0	338.9	347.8	398.9	414.6	440.1	447.1	467.4	474.5	6 - RENEWABLES
3055.2	3546.5	3974.7	4397.0	4830.3	5184.8	5507.7	5886.5	6229.7	■■■■■ T O T A L ■■■■■

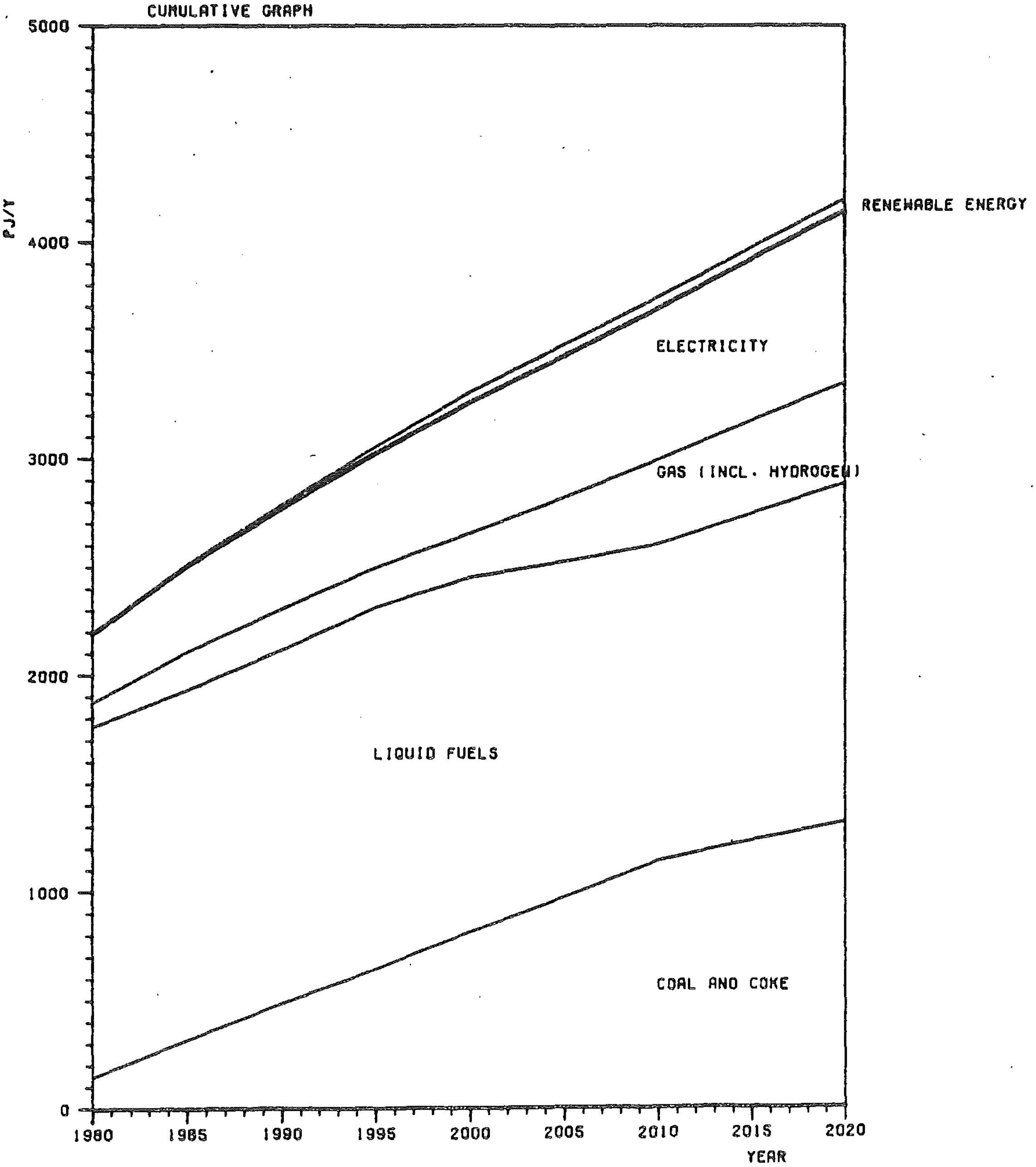


SINGLE SCENARIO FOR SPAIN RUN TSPINN SCENARIO: PS-I/LIM NUC DATE: 11/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
148.4	318.4	485.3	643.5	813.8	971.7	1141.4	1232.2	1317.3	1	- COAL AND COKE
1614.5	1612.3	1631.7	1669.4	1637.6	1550.0	1459.1	1511.6	1565.0	2	- LIQUID FUELS
110.2	178.1	190.7	184.7	202.5	297.0	392.7	428.6	464.7	3	- GAS (INCL. HYDROGEN)
320.8	396.8	464.0	525.6	605.7	654.2	698.5	749.3	797.6	4	- ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	- PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	- DISTRICT HEAT
0.0	5.0	17.4	31.4	45.4	51.6	51.6	51.6	52.4	7	- RENEWABLE ENERGY
2193.9	2510.6	2789.1	3054.6	3305.0	3524.5	3743.3	3973.3	4197.0		***** T O T A L *****

CUMULATIVE GRAPH

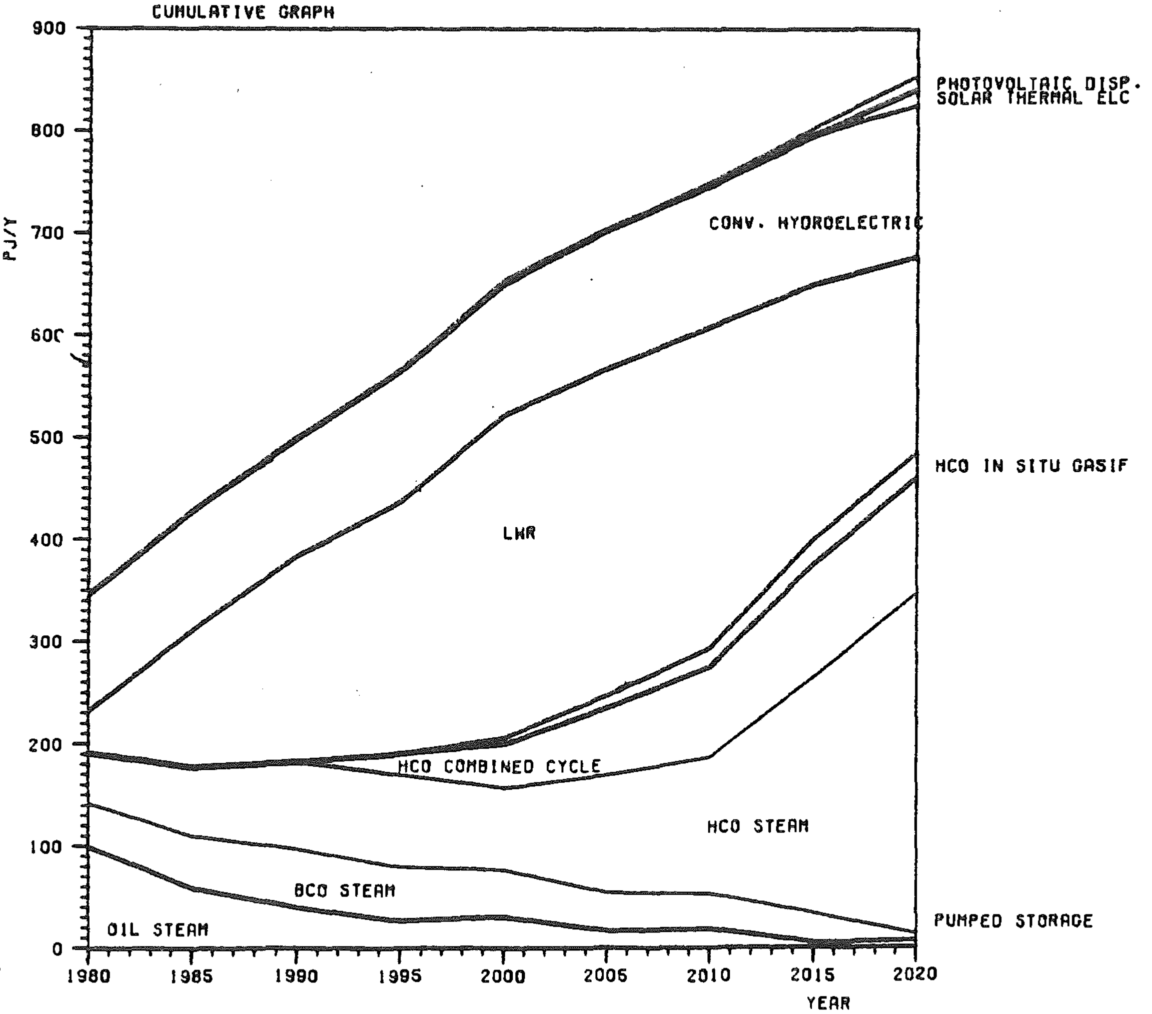


SINGLE SCENARIO FOR SPAIN RUN TSPINN SCENARIO: PS-1/LIM NUC DATE: 11/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
99.0	58.8	39.7	26.6	30.5	16.6	18.5	5.0	6.7	1	OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	FOSSIL COGENERATION
42.5	50.8	57.3	52.7	46.0	37.7	34.4	28.9	6.4	4	BCO STEAM
49.1	67.1	85.5	90.0	80.1	114.9	134.0	231.2	333.9	5	HCO STEAM
0.0	0.0	0.0	20.4	43.1	65.8	88.5	111.1	113.3	6	HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	HCO MHO
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	6.2	12.3	18.5	24.6	24.6	9	HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	A	GAS FUEL CELL
41.3	134.3	201.4	247.4	316.5	320.3	314.5	249.3	191.8	B	LWR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	C	HTR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	D	LMFBR
114.1	116.9	115.7	128.8	131.8	136.9	138.4	146.6	148.7	E	CONV. HYDROELECTRIC
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4	F	SOLAR THERMAL ELC
0.0	0.0	0.0	-0.2	-2.6	-0.9	0.0	-1.0	-1.0	G	PUMPED STORAGE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	H	WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I	GEOTHERMAL HDR
0.0	0.0	0.0	0.0	0.0	0.0	2.9	7.8	13.6	J	PHOTOVOLTAIC DISP.
346.0	427.9	499.6	565.7	651.6	703.6	749.7	803.5	854.4	*****	T O T A L *****

CUMULATIVE GRAPH

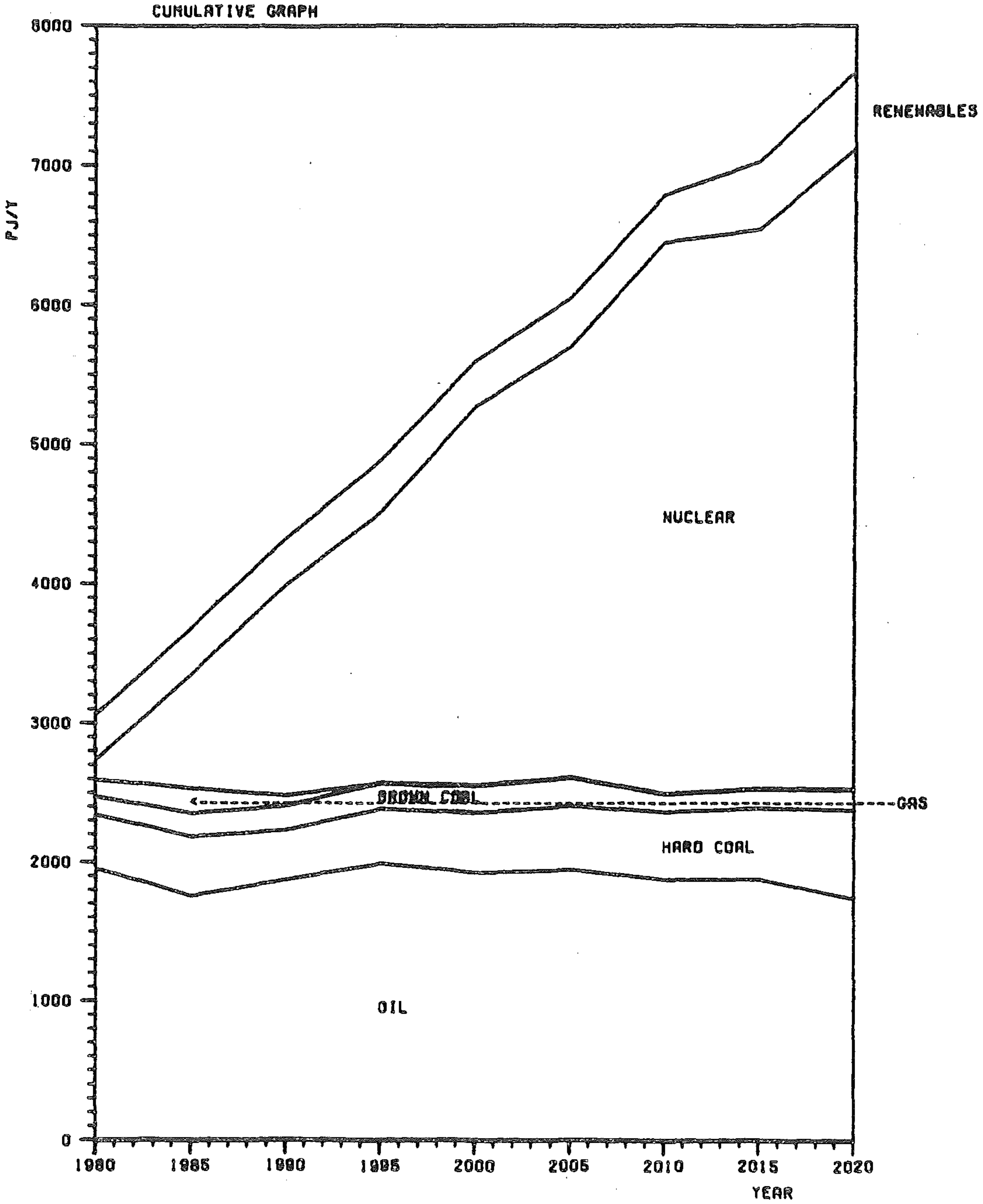


SINGLE SCENARIO FOR SPAIN RUN TSP4LF SCENARIO: SP-4/1(80% LIM FOS) DATE: 15/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1956.4	1756.4	1876.1	1993.5	1927.4	1948.4	1879.1	1879.0	1738.7	1 - OIL
384.0	425.0	354.0	391.5	429.0	457.0	465.0	513.0	641.0	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	129.1	138.4	147.6	3 - BROWN. COAL
120.3	180.3	76.2	0.0	0.0	0.0	0.0	0.0	0.0	4 - GAS
141.4	813.2	1507.8	1939.4	2722.8	3096.8	3980.7	4014.7	4598.5	5 - NUCLEAR
326.0	334.9	333.8	373.9	326.8	348.1	337.6	486.1	553.0	6 - RENEWABLES
3059.5	3679.8	4323.9	4884.6	5602.6	6054.4	6791.5	7031.2	7678.8	===== T O T A L =====

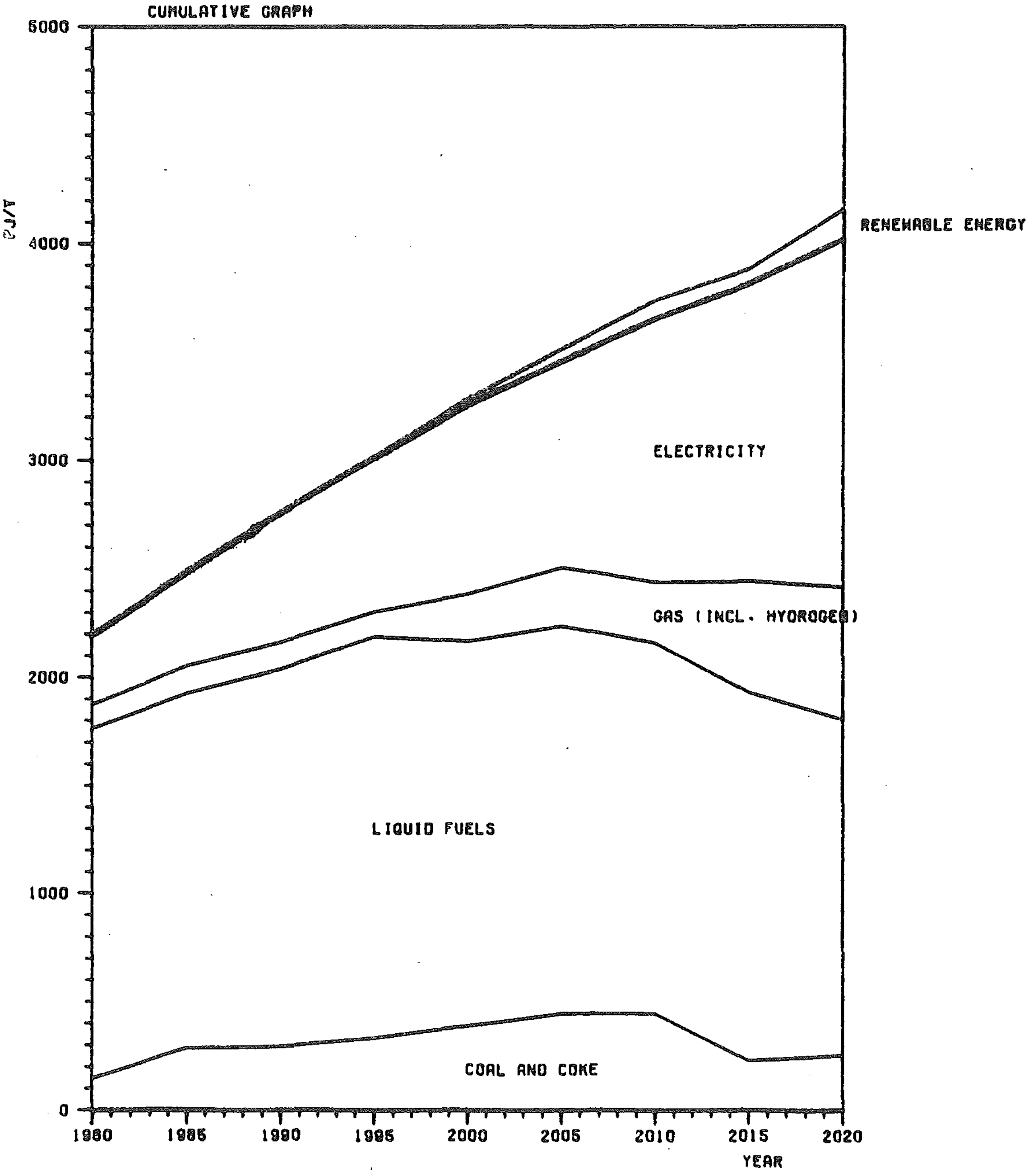
CUMULATIVE GRAPH



SINGLE SCENARIO FOR SPAIN RUN TSP4LF SCENARIO: SP-4/1(60% LIN FOS) DATE: 15/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
148.4	268.7	294.9	335.2	390.2	448.3	447.6	228.2	256.3	1 - COAL AND COKE
1614.5	1636.0	1746.7	1853.8	1777.8	1790.8	1711.5	1702.3	1550.0	2 - LIQUID FUELS
110.2	128.7	122.1	114.7	217.8	270.6	280.9	516.0	612.7	3 - GAS (INCL. HYDROGEN)
320.8	432.1	597.5	710.6	873.8	951.1	1216.1	1371.1	1606.6	4 - ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5 - PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6 - DISTRICT HEAT
0.0	1.9	3.9	5.8	28.7	56.9	85.6	68.4	135.4	7 - RENEWABLE ENERGY
2193.9	2467.4	2765.1	3020.1	3288.3	3517.7	3741.7	3886.0	4161.0	===== T O T A L =====

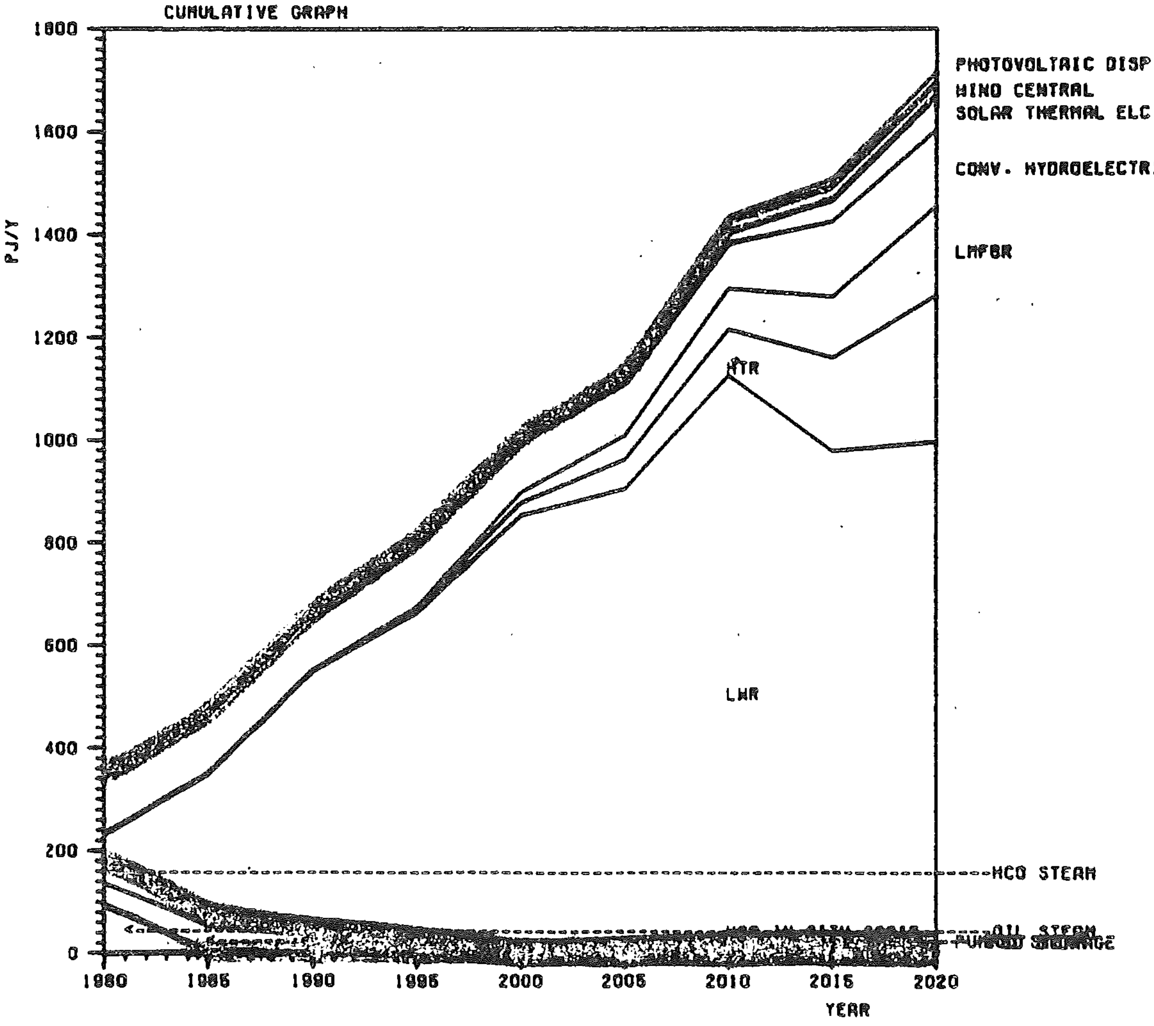


SINGLE SCENARIO FOR SPAIN RUN TSP4LF SCENARIO: SP-4/1(80% LIM FOS) DATE: 15/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
94.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1	- OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	- FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	- FOSSIL COGENERATION
42.5	51.0	47.6	29.8	0.0	0.0	0.0	0.0	0.0	4	- BCO STEAM
49.1	27.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	- HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6	- HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	- HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8	- HCO FLUIDIZED BED
0.0	0.0	2.7	8.9	18.5	28.2	35.0	38.5	38.5	9	- HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	A	- GAS FUEL CELL
46.9	269.8	500.2	625.9	834.5	876.5	1091.5	939.8	959.0	B	- LWR
0.0	0.0	0.0	6.1	25.5	57.7	88.9	181.5	285.6	C	- HTR
0.0	0.0	0.0	4.4	20.0	46.6	79.8	119.7	172.9	D	- LMFBR
114.1	116.9	115.5	128.8	104.3	101.9	88.2	146.4	148.7	E	- CONV. HYDROELECTRIC
0.0	0.0	0.0	1.9	4.4	10.7	23.3	42.2	67.4	F	- SOLAR THERMAL ELC
0.0	-0.3	0.0	0.0	0.0	0.0	0.0	-0.2	-2.6	G	- PUMPED STORAGE
0.0	0.0	0.0	3.2	6.4	12.8	19.3	25.7	25.7	H	- WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I	- GEOTHERMAL HOR
0.0	0.0	0.0	0.0	1.9	5.8	9.7	15.5	21.4	J	- PHOTOVOLTAIC DISP.
346.6	466.4	666.0	809.0	1015.5	1140.2	1435.7	1509.1	1716.6	*****	T O T A L *****

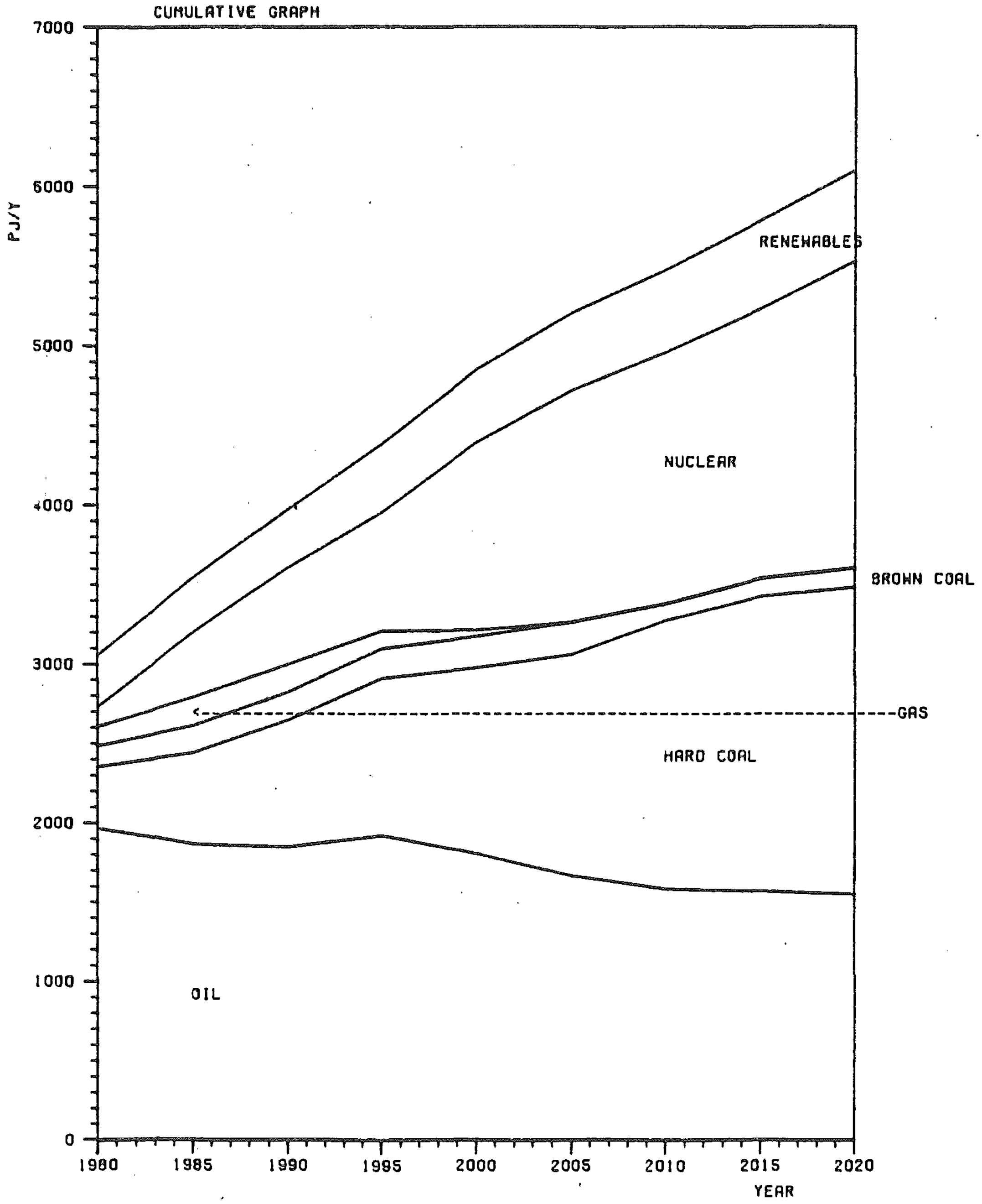
CUMULATIVE GRAPH



SINGLE SCENARIO FOR SPAIN RUN TSPRP4 SCENARIO: RP-4 DATE: 11/11/79

TABLE 2: PRIMARY ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1868.8	1849.8	1922.0	1806.9	1667.5	1584.7	1569.4	1551.8	1 - OIL
384.0	572.1	799.5	990.8	1171.0	1394.3	1691.5	1856.1	1931.5	2 - HARD COAL
131.4	170.0	176.0	186.3	196.6	204.1	105.6	113.2	120.7	3 - BROWN COAL
120.3	180.3	174.7	110.5	40.9	0.0	0.0	0.0	0.0	4 - GAS
124.5	404.7	607.0	746.7	1181.5	1457.5	1577.5	1695.2	1929.8	5 - NUCLEAR
326.0	347.1	367.3	430.2	456.1	484.0	517.8	553.5	567.3	6 - RENEWABLES
3055.2	3543.0	3974.3	4385.5	4853.0	5207.4	5477.1	5787.4	6101.1	***** T O T A L *****

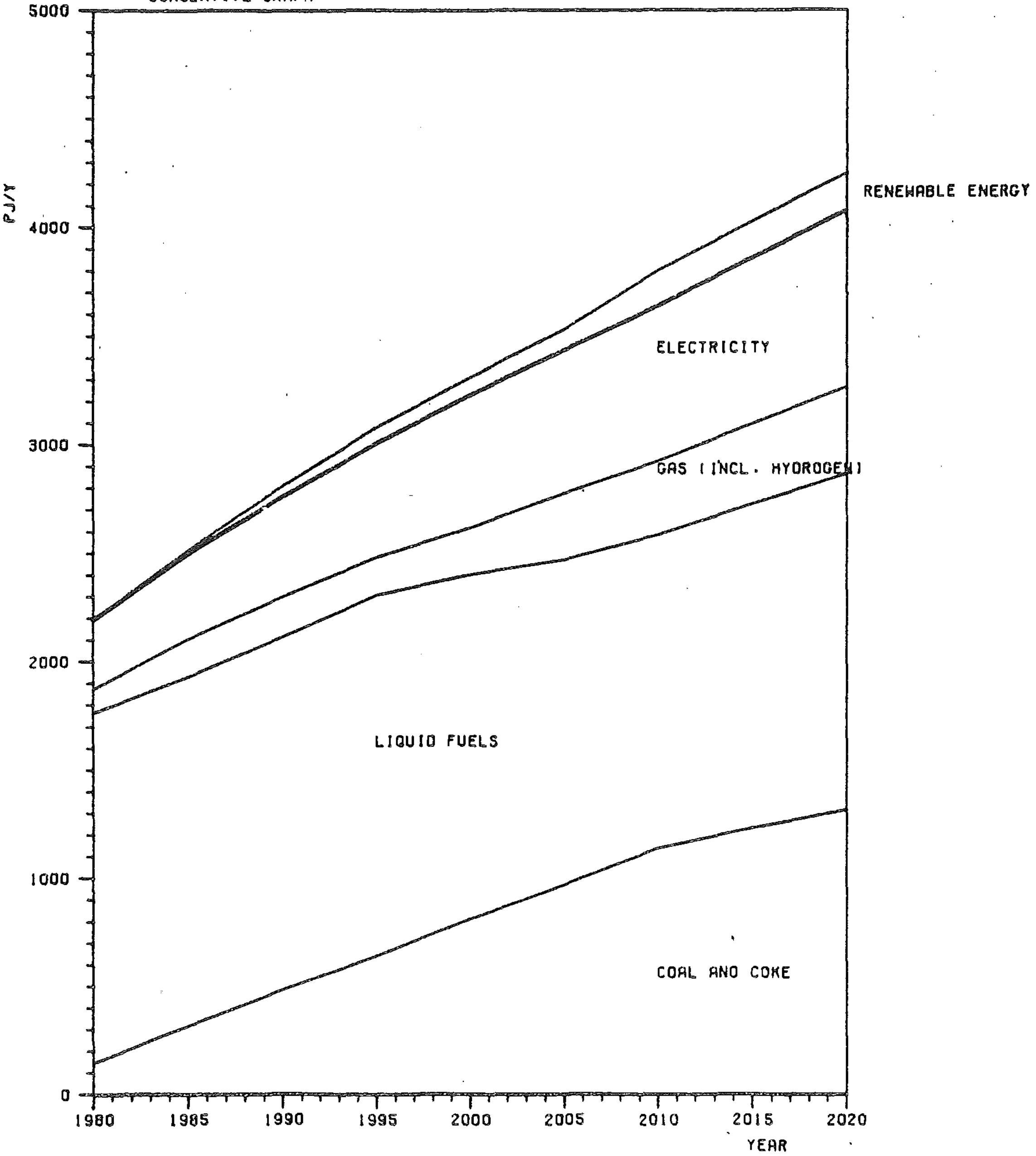


SINGLE SCENARIO FOR SPAIN RUN TSPRP4 SCENARIO: RP-4 DATE: 11/11/79

TABLE 4: FINAL ENERGY BY FUEL (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
148.4	318.4	485.3	643.5	813.8	971.7	1141.4	1232.2	1317.3	1 - COAL AND COKE
1614.5	1612.4	1630.1	1665.8	1589.9	1500.5	1446.0	1497.9	1550.0	2 - LIQUID FUELS
110.2	175.1	186.5	175.4	216.8	306.6	339.4	369.3	401.1	3 - GAS (INCL. HYDROGEN)
320.8	392.6	462.7	524.4	611.0	660.9	716.1	766.0	813.6	4 - ELECTRICITY
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5 - PROCESS HEAT
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6 - DISTRICT HEAT
0.0	17.8	48.2	73.7	81.4	96.3	160.9	166.6	172.1	7 - RENEWABLE ENERGY
2193.9	2516.3	2812.8	3082.8	3312.9	3536.0	3803.8	4032.0	4254.1	===== T O T A L =====

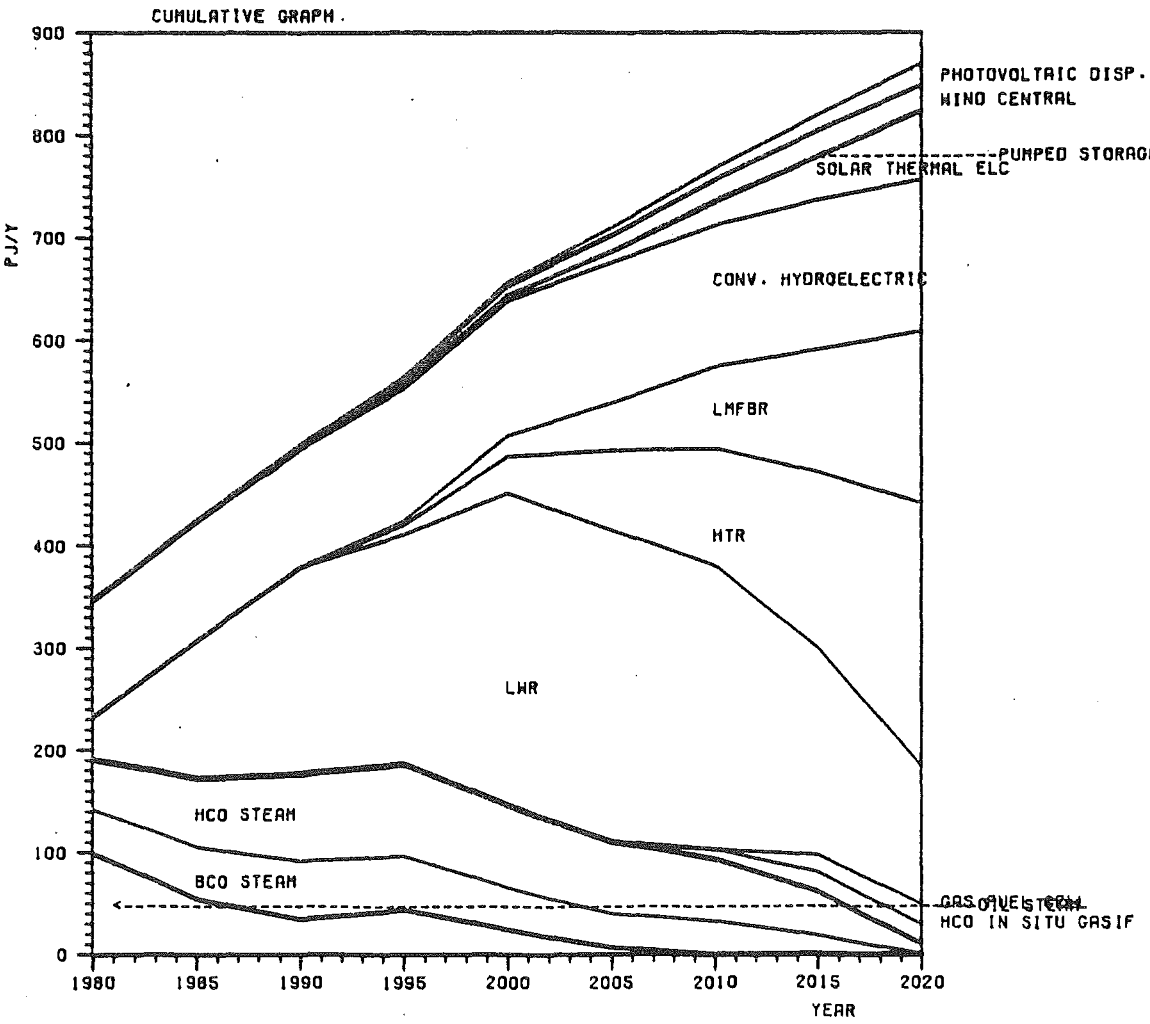
CUMULATIVE GRAPH



"SINGLE SCENARIO FOR SPAIN RUN TSPRP4 SCENARIO: RP-4 DATE: 11/11/79

TABLE 8: ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
99.0	54.3	34.3	43.8	24.5	6.8	0.0	0.0	0.0	1 - OIL STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2 - FOSSIL GAS TURBINE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3 - FOSSIL COGENERATION
42.5	50.8	57.3	52.9	40.9	33.1	32.7	18.4	0.0	4 - BCO STEAM
49.1	67.1	85.5	90.0	80.8	70.3	61.0	42.5	9.8	5 - HCO STEAM
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6 - HCO COMBINED CYCLE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7 - HCO MHD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8 - HCO FLUIDIZED BED
0.0	0.0	0.0	0.0	0.0	0.0	9.6	19.3	19.3	9 - HCO IN SITU GASIF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	19.8	A - GAS FUEL CELL
41.3	134.3	201.4	224.1	304.8	304.8	277.0	202.4	135.3	B - LWR
0.0	0.0	0.0	9.3	36.1	77.9	114.5	171.9	256.9	C - HTR
0.0	0.0	0.0	4.4	20.0	46.6	79.8	119.7	168.0	D - LMFBR
114.1	116.9	115.7	128.7	131.7	136.8	138.0	146.1	147.6	E - CONV. HYDROELECTRIC
0.0	0.0	0.0	2.5	5.0	11.3	23.9	42.9	68.1	F - SOLAR THERMAL ELC
0.0	0.0	0.0	-0.1	-0.6	-1.1	-2.2	-1.4	-1.6	G - PUMPED STORAGE
0.0	0.0	3.2	6.4	9.6	16.0	22.5	25.7	25.7	H - WIND CENTRAL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	I - GEOTHERMAL HDR
0.0	0.0	0.8	2.3	4.3	7.8	11.3	15.5	21.4	J - PHOTOVOLTAIC DISP.
346.0	423.4	498.2	564.3	657.1	710.3	768.1	820.0	870.3	■■■■■ T O T A L ■■■■■



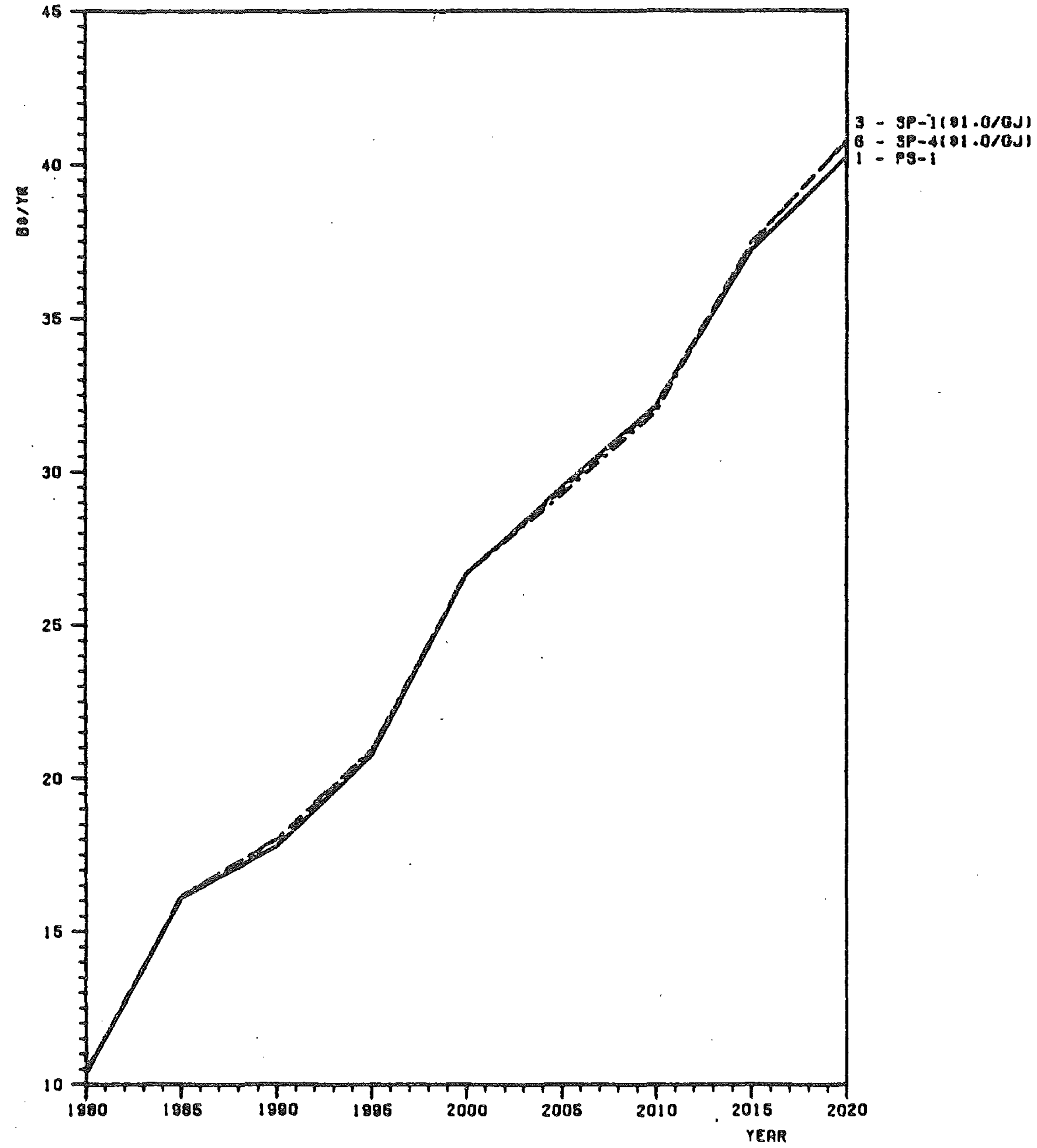
5.3 Comparison of all Scenarios

NOTE : For clarity of the graphs, only scenarios PS-1, SP-1/1.0 and SP-4/1.0 are plotted.

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 1: TOTAL SYSTEM COST (B$/YR)

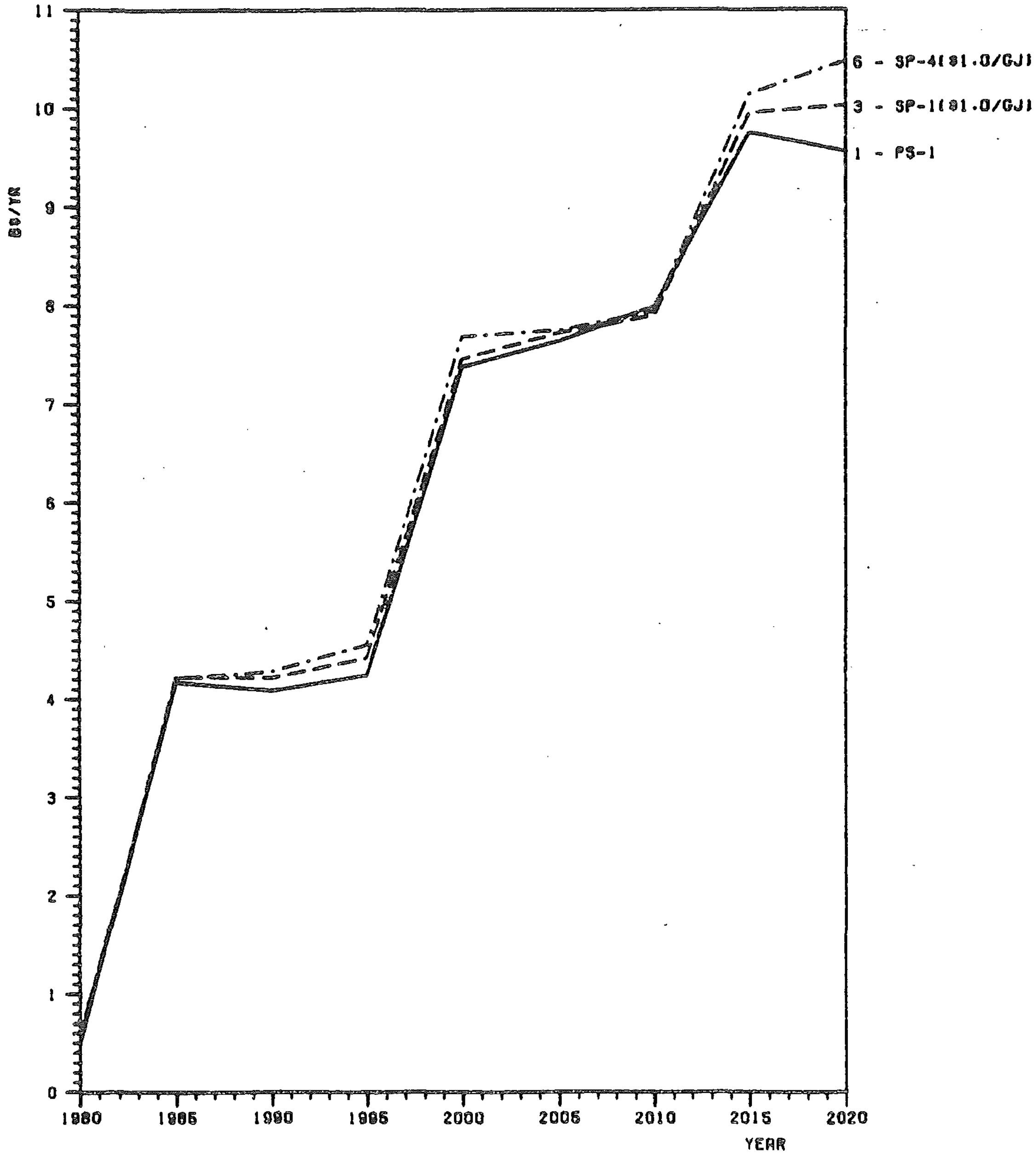
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
10.4	16.1	17.8	20.7	26.7	29.5	32.2	37.2	40.2	1 - PS-1
10.4	16.6	19.0	22.8	29.4	32.0	34.7	38.5	40.2	2 - PS-1 OIL C
10.4	16.1	18.0	20.9	26.7	29.4	32.1	37.5	40.7	3 - SP-1($1.0/GJ)
10.5	16.4	17.8	20.8	26.7	29.5	32.3	38.0	41.0	4 - SP-1
10.4	16.1	17.8	20.7	26.6	29.2	31.7	37.0	40.3	5 - PS-4
10.4	16.1	18.0	20.9	26.7	29.2	32.0	37.4	40.8	6 - SP-4($1.0/GJ)
10.8	19.4	20.4	24.7	32.1	37.7	43.3	48.0	49.5	7 - SP-4/1(LIM FOS 80%)
10.4	16.2	18.1	21.0	27.0	29.7	33.0	38.1	41.4	8 - RP-4
10.4	16.1	17.9	20.9	27.0	30.0	33.2	38.7	42.0	9 - PS-1 COAL C
10.4	16.1	17.8	20.8	26.7	30.1	33.4	39.8	44.7	A - PS-1 LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 16/11/79

TABLE 2: INVESTMENT IN TECHNOLOGY (B$/YR)

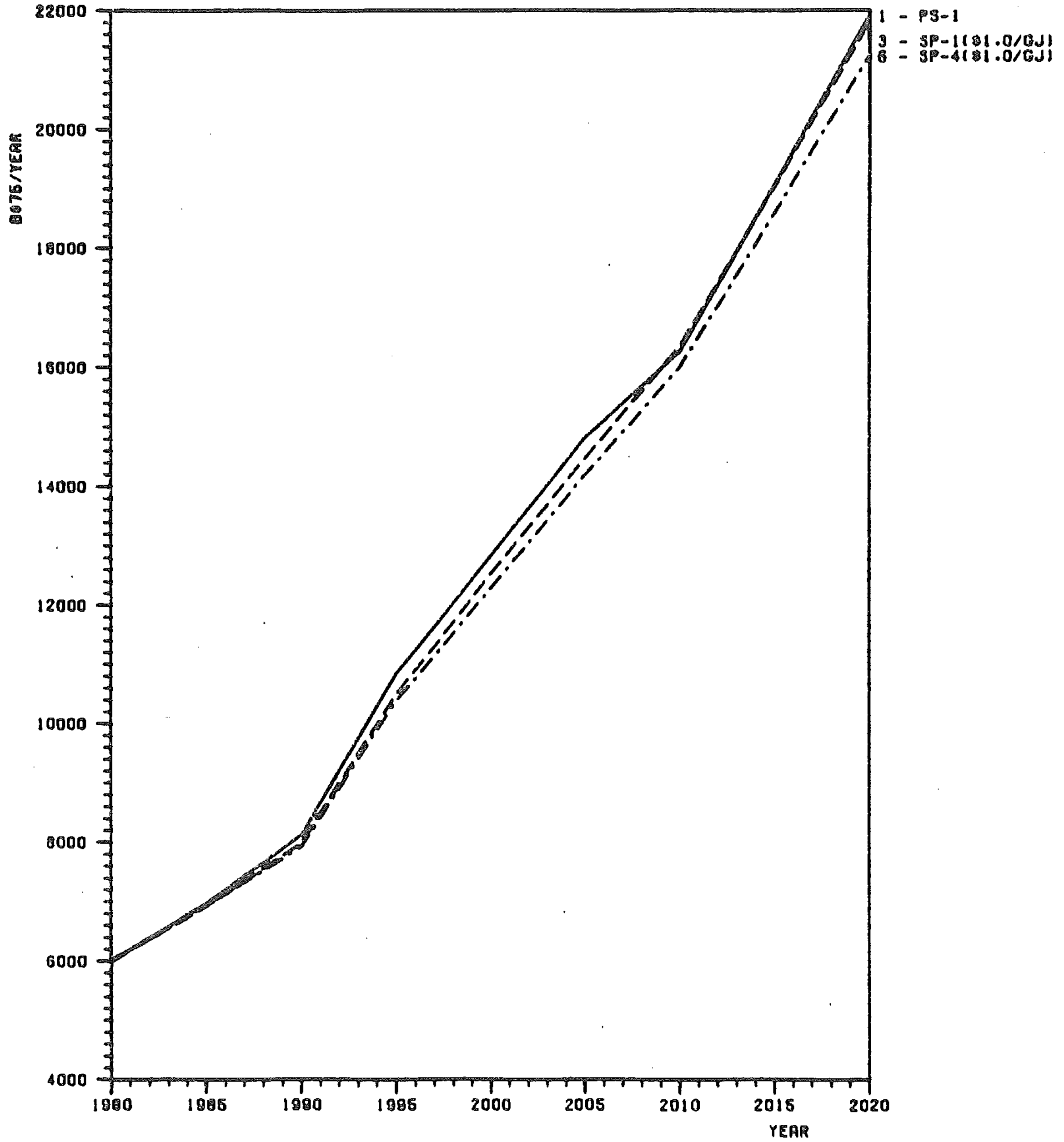
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.5	4.2	4.1	4.2	7.4	7.6	8.0	9.8	9.6	1 - PS-1
0.5	4.2	4.1	4.4	7.5	7.6	7.8	9.8	9.5	2 - PS-1 OIL C
0.5	4.2	4.2	4.4	7.5	7.7	7.9	10.0	10.0	3 - SP-1($1.0/GJ)
0.5	4.5	4.1	4.3	7.6	7.7	7.9	10.3	10.2	4 - SP-1
0.5	4.2	4.1	4.3	7.5	7.7	7.7	9.7	9.8	5 - PS-4
0.5	4.2	4.3	4.6	7.7	7.8	7.9	10.1	10.5	6 - SP-4($1.0/GJ)
0.6	6.0	4.8	5.4	8.5	9.7	10.0	13.0	12.5	7 - SP-4/1(LIM FOS 80%)
0.5	4.3	4.4	4.6	7.9	8.3	8.9	10.7	10.8	8 - RP-4
0.5	4.2	4.1	4.2	7.4	7.5	7.9	9.6	9.5	9 - PS-1 COAL C
0.5	4.2	4.1	4.2	7.0	7.2	7.3	9.2	9.5	A - PS-1 LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 16/11/78

TABLE 3: EXPENDITURE ON FUEL (B$75/YEAR)

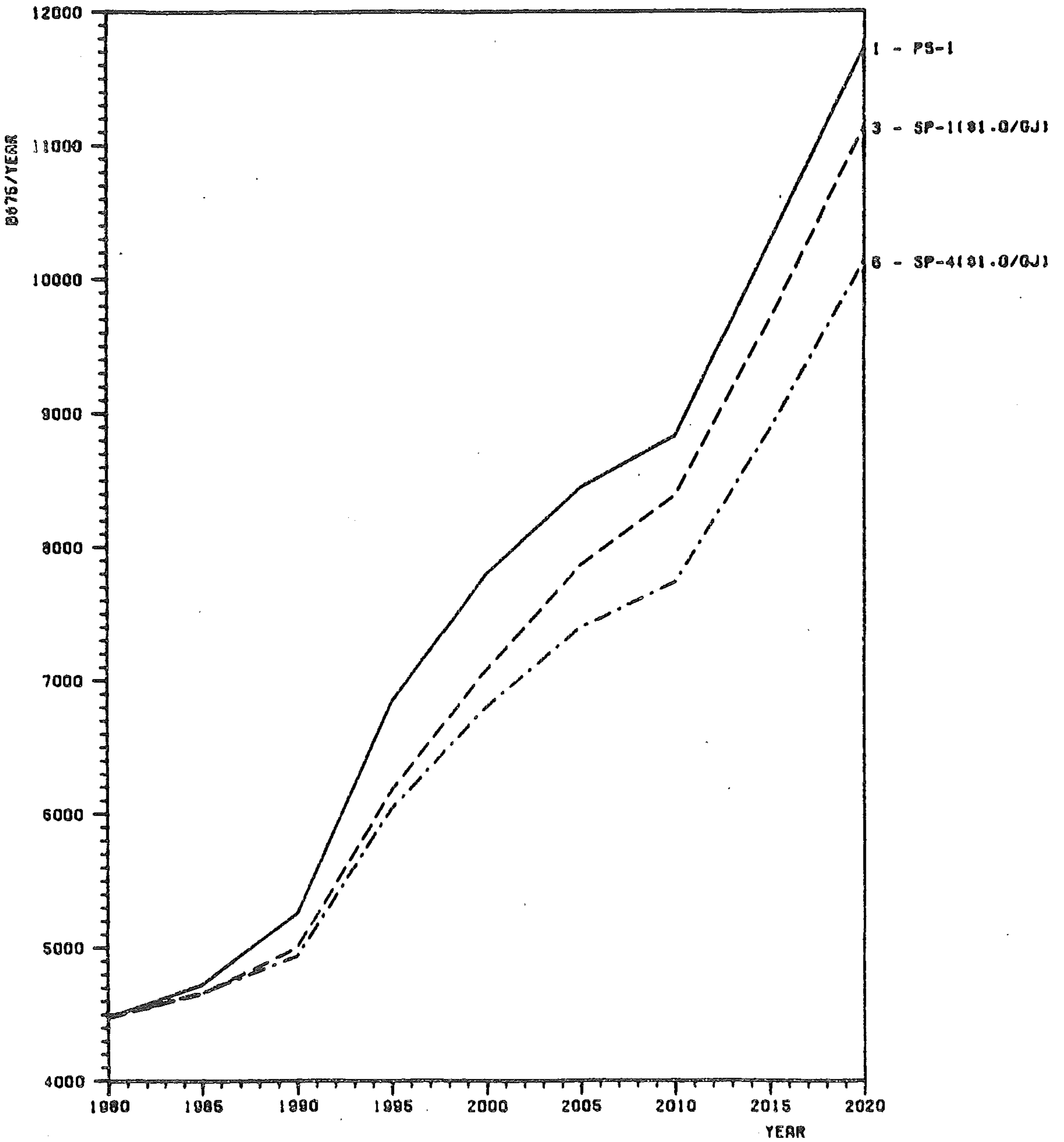
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
6012.0	6972.9	8120.4	10846.2	12841.9	14828.6	16264.9	19068.3	21918.4	1 - PS-1
6012.0	7493.0	9276.6	12702.1	15196.0	17237.5	18929.3	20331.5	21932.3	2 - PS-1 OIL C
6012.0	6919.5	7977.8	10494.2	12533.3	14481.1	16368.6	19034.1	21801.0	3 - SP-1($1.0/GJ)
6034.5	6714.8	7894.8	10495.5	12537.1	14487.0	16383.4	19013.1	21829.3	4 - SP-1
6012.0	6960.2	8111.7	10758.9	12680.5	14445.8	16245.5	18906.9	21702.1	5 - PS-4
6012.0	6929.5	7926.2	10385.8	12283.1	14200.6	16001.1	18688.4	21234.6	6 - SP-4($1.0/GJ)
6140.0	6692.1	7649.6	10190.1	12468.7	15066.1	17388.5	19336.8	19497.1	7 - SP-4/1(LIM FOS 60%)
6012.0	6942.6	8048.6	10743.6	12579.9	14287.5	16016.8	18738.7	21407.2	8 - RP-4
6012.0	7001.7	8221.6	11044.1	13200.2	15498.7	17383.9	20696.4	23748.8	9 - PS-1 COAL C
6012.0	6972.9	8115.6	10799.2	13287.9	15849.5	18424.5	22292.8	26397.4	A - PS-1 LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 4: EXPENDITURE ON OIL IMPORT (B$75/YEAR)

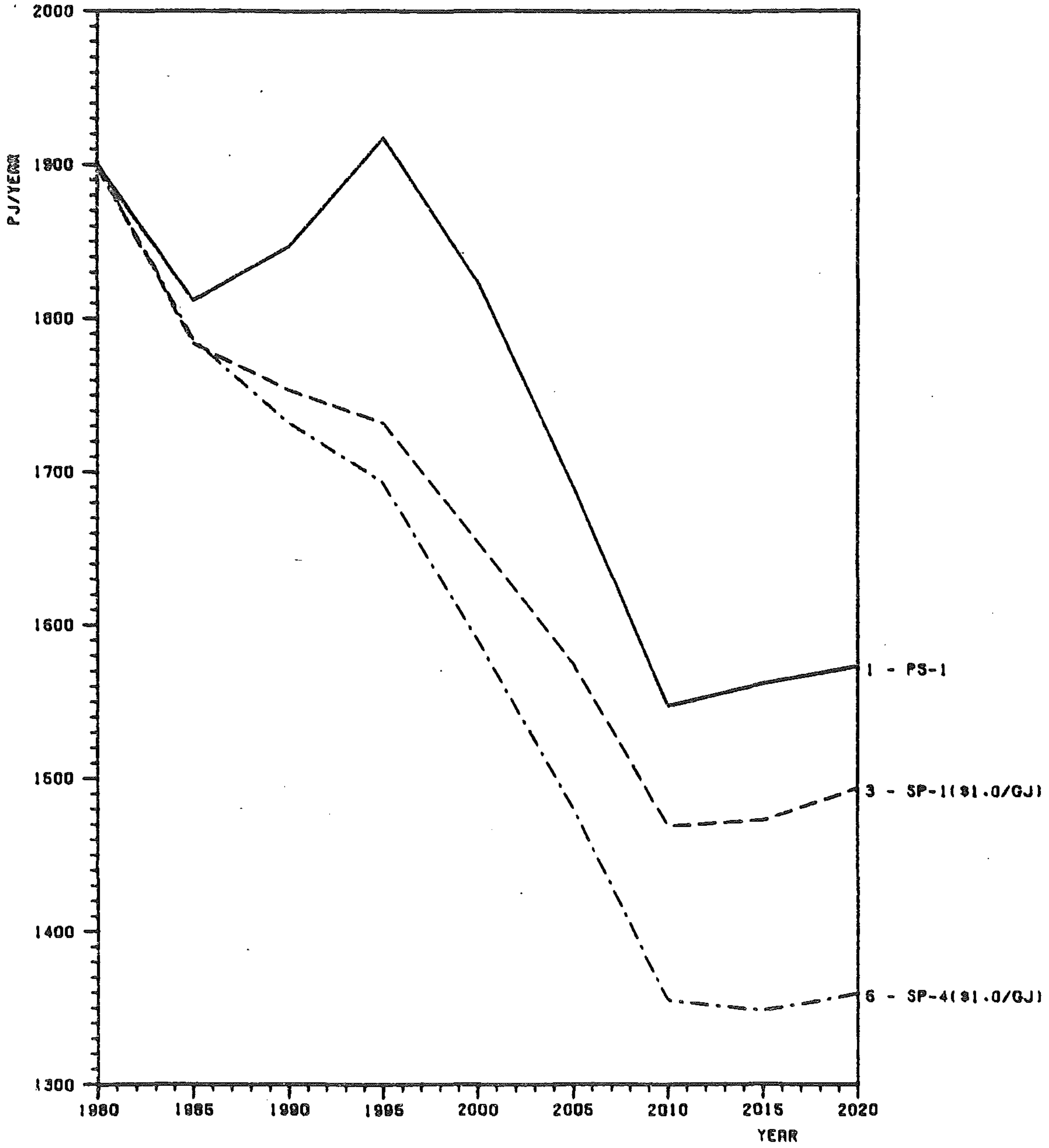
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
4484.0	4727.9	5262.4	6843.0	7803.6	8448.2	8828.7	10284.1	11724.6	1 - PS-1
4484.0	5248.1	6320.7	8400.4	9767.2	10672.3	11300.1	11436.9	11740.8	2 - PS-1 OIL C
4484.0	4656.1	4996.6	6181.8	7079.9	7868.9	8383.3	9698.1	11133.1	3 - SP-1($1.0/GJ)
4484.0	4437.0	4912.3	6180.7	7073.3	7863.2	8353.5	9636.3	11016.8	4 - SP-1
4484.0	4715.2	5266.1	6825.0	7783.4	8414.1	9068.4	10762.7	12069.7	5 - PS-4
4484.0	4662.3	4935.2	6042.6	6804.9	7399.9	7734.9	8877.6	10133.2	6 - SP-4($1.0/GJ)
4484.0	4437.0	5299.4	7117.0	8249.3	9742.1	10729.6	12382.5	12970.8	7 - SP-4/1(LIM FOS 80%)
4484.0	4697.6	5224.3	6861.4	7733.4	8337.4	9048.8	10342.1	11576.3	8 - RP-4
4484.0	4727.9	5262.4	6843.0	7907.5	8750.5	9318.6	11166.1	13166.6	9 - PS-1 COAL C
4484.0	4727.9	5268.6	6717.8	7916.2	8502.9	8897.6	10207.4	11771.8	A - PS-1 LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 9: NET OIL IMPORT (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1900.0	1811.5	1846.5	1916.8	1823.3	1688.6	1546.2	1560.6	1571.7	1 - PS-1
1900.0	1797.3	1816.3	1798.8	1666.8	1600.1	1512.7	1531.1	1571.7	2 - PS-1 OIL C
1900.0	1783.9	1753.2	1731.6	1654.2	1573.8	1468.2	1471.6	1492.4	3 - SP-1($1.0/GJ)
1900.0	1700.0	1723.6	1731.3	1652.6	1570.6	1463.0	1462.3	1476.8	4 - SP-1
1900.0	1806.6	1847.7	1911.8	1818.5	1682.8	1588.2	1633.2	1620.6	5 - PS-4
1900.0	1786.3	1731.7	1692.6	1589.9	1480.0	1354.6	1347.1	1358.3	6 - SP-4($1.0/GJ)
1900.0	1700.0	1859.4	1893.5	1927.4	1948.4	1879.1	1879.0	1738.7	7 - SP-4/1(LIM FOS 80%)
1900.0	1799.8	1833.1	1922.0	1806.9	1667.5	1584.7	1569.4	1551.8	8 - RP-4
1900.0	1811.5	1846.5	1916.8	1847.6	1750.1	1632.0	1694.4	1763.5	9 - PS-1 COAL C
1900.0	1811.5	1848.6	1881.7	1849.4	1700.6	1575.8	1548.9	1578.0	A - PS-1 LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 10: NET GAS IMPORT (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
50.0	110.0	104.6	138.9	81.5	52.4	0.0	0.0	0.0	1 - PS-1
50.0	110.0	134.8	209.7	139.9	60.7	0.0	0.0	0.0	2 - PS-1 OIL C
50.0	110.0	134.8	206.3	124.8	29.1	0.0	0.0	0.0	3 - SP-1($1.0/GJ)
50.0	110.0	134.8	206.3	124.8	29.1	0.0	0.0	0.0	4 - SP-1
50.0	110.0	101.3	119.0	41.9	0.0	0.0	0.0	0.0	5 - PS-4
50.0	110.0	128.8	174.9	59.9	0.0	0.0	0.0	0.0	6 - SP-4($1.0/GJ)
50.0	110.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7 - SP-4/1(LIM FOS 80%)
50.0	110.0	98.5	110.5	40.9	0.0	0.0	0.0	0.0	8 - RP-4
50.0	110.0	104.6	138.9	55.4	40.7	20.6	0.0	0.0	9 - PS-1 COAL C
50.0	110.0	103.0	155.8	139.0	199.0	287.3	232.4	142.3	A - PS-1 LIM NUC

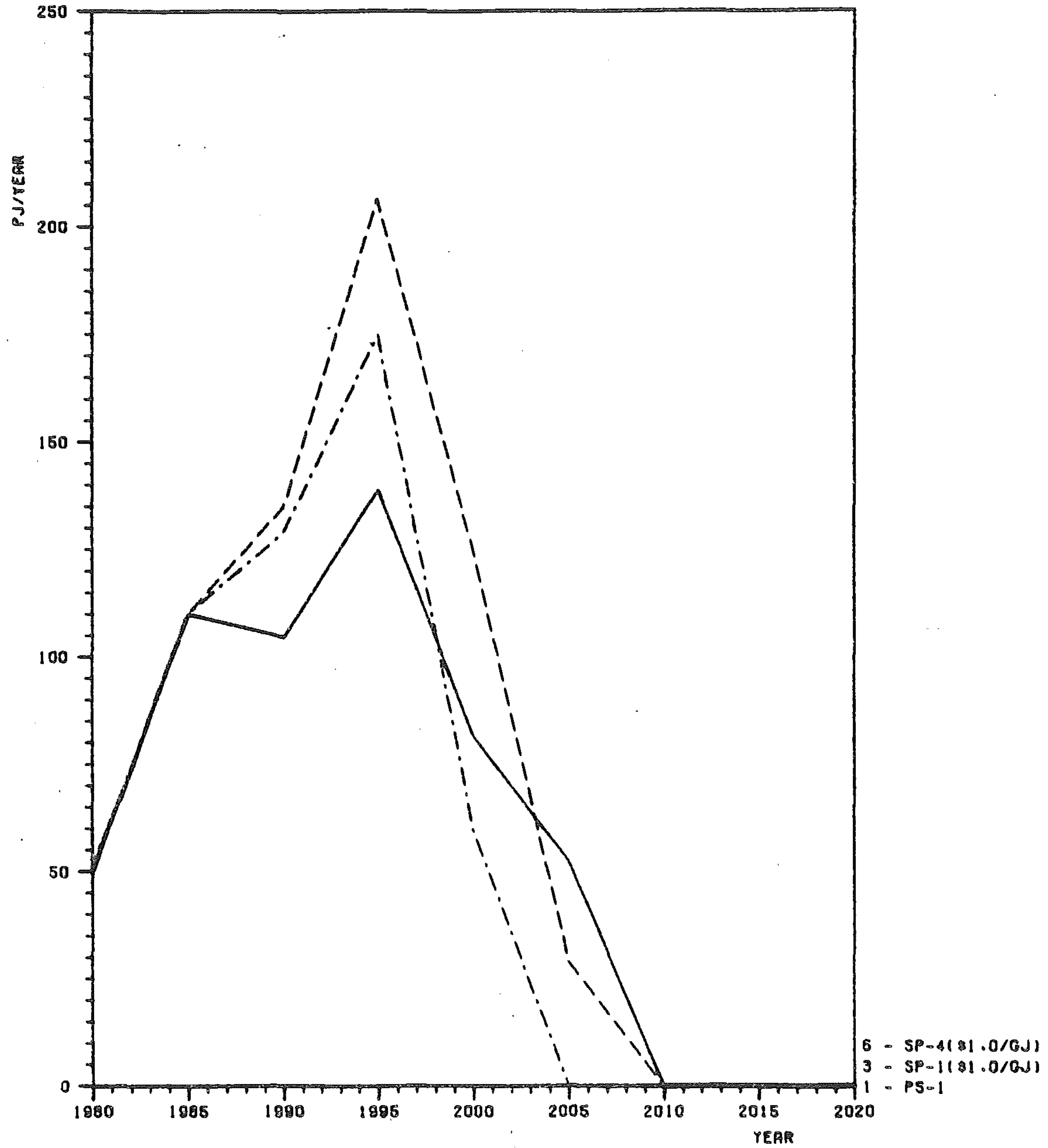


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TABLE 11: NET COAL IMPORT (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
80.0	227.1	445.5	595.4	728.1	962.5	1292.7	1440.4	1521.5	1 - PS-1
80.0	227.1	445.5	614.9	801.0	1037.6	1379.1	1403.5	1521.4	2 - PS-1 OIL C
80.0	227.1	445.2	625.7	847.8	1135.3	1532.2	1639.1	1694.0	3 - SP-1($1.0/GJ)
80.0	227.1	445.6	626.0	849.1	1135.4	1521.7	1617.1	1674.0	4 - SP-1
80.0	227.1	445.6	599.3	742.2	937.5	1223.2	1247.1	1311.4	5 - PS-4
80.0	227.1	464.8	710.4	1006.1	1304.4	1699.6	1813.7	1861.0	6 - SP-4($1.0/GJ)
80.0	80.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	7 - SP-4/1(LIM FOS 80%)
80.0	227.1	445.5	599.3	742.0	937.3	1206.5	1343.1	1390.5	8 - RP-4
80.0	227.1	445.6	595.4	728.1	878.7	1087.1	1152.1	1085.0	9 - PS-1 COAL C
80.0	227.1	445.5	637.0	847.8	1218.6	1658.9	2260.1	2795.1	A - PS-1 LIM NUC

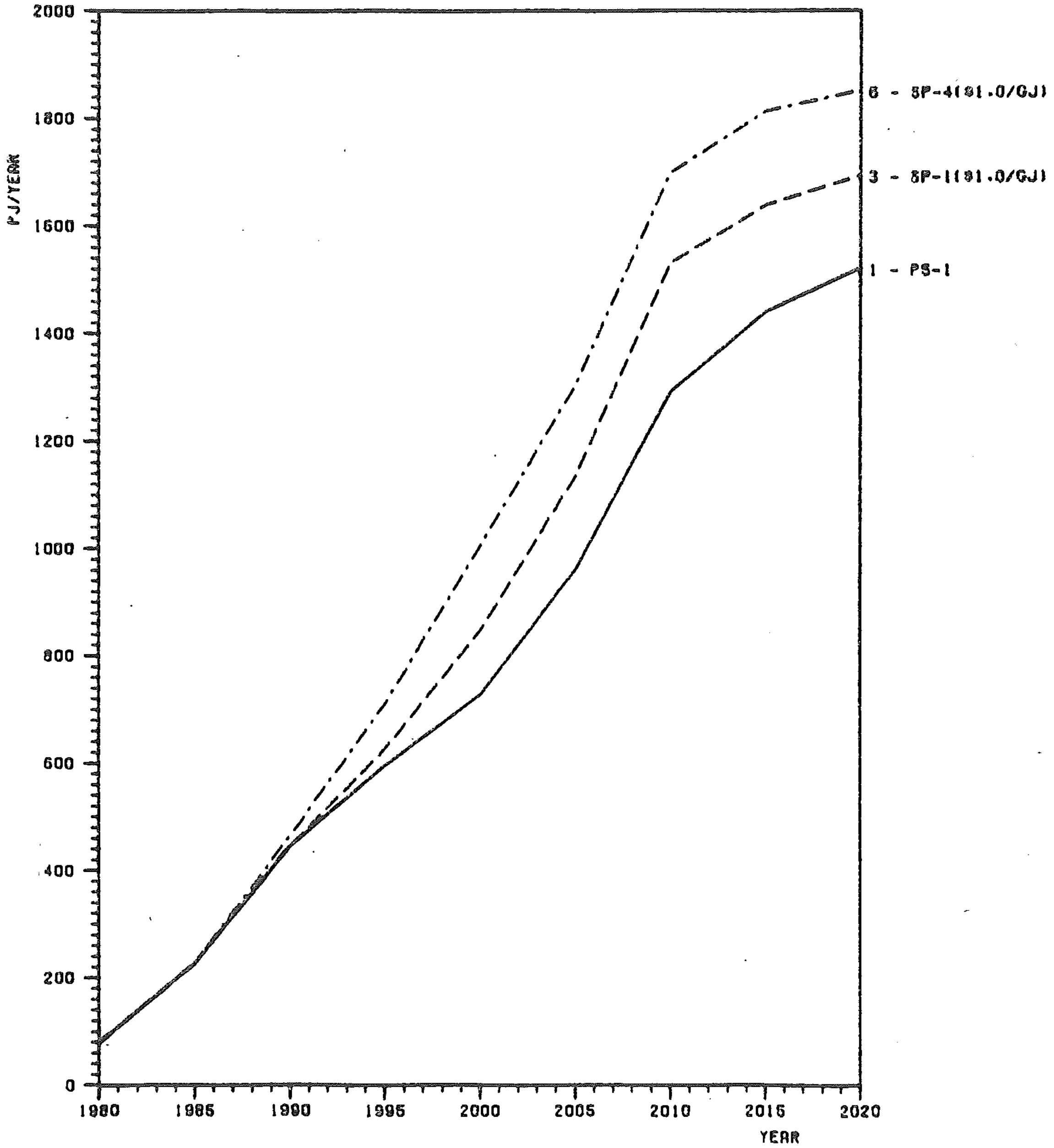

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TABLE 12: NET URANIUM IMPORT (MG/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
853.8	554.2	446.7	923.9	717.4	911.6	1953.1	893.9	0.0	1 - PS-1
853.8	554.2	546.2	1100.9	841.4	880.7	1945.4	900.4	0.0	2 - PS-1 OIL C
853.8	713.4	756.2	1126.0	830.5	829.5	1945.7	1061.8	0.0	3 - SP-1($1.0/GJ)
1069.7	837.2	761.4	1138.0	870.5	919.8	2233.9	1365.6	0.0	4 - SP-1
853.8	554.2	418.3	872.2	655.0	649.3	1577.4	684.0	0.0	5 - PS-4
853.8	746.2	727.9	1081.1	754.6	706.4	1624.3	860.7	0.0	6 - SP-4($1.0/GJ)
2153.3	2410.3	3258.9	4230.8	4991.1	5834.5	9218.7	5887.7	0.0	7 - SP-4/1(LIM FOS 90%)
853.8	554.2	313.5	729.5	422.2	308.1	944.3	439.1	0.0	8 - RP-4
853.8	554.2	446.7	923.9	716.7	987.1	2034.2	1348.8	0.0	9 - PS-1 COAL C
853.8	554.2	380.5	633.0	152.2	0.0	891.9	601.3	0.0	A - PS-1 LIM NUC

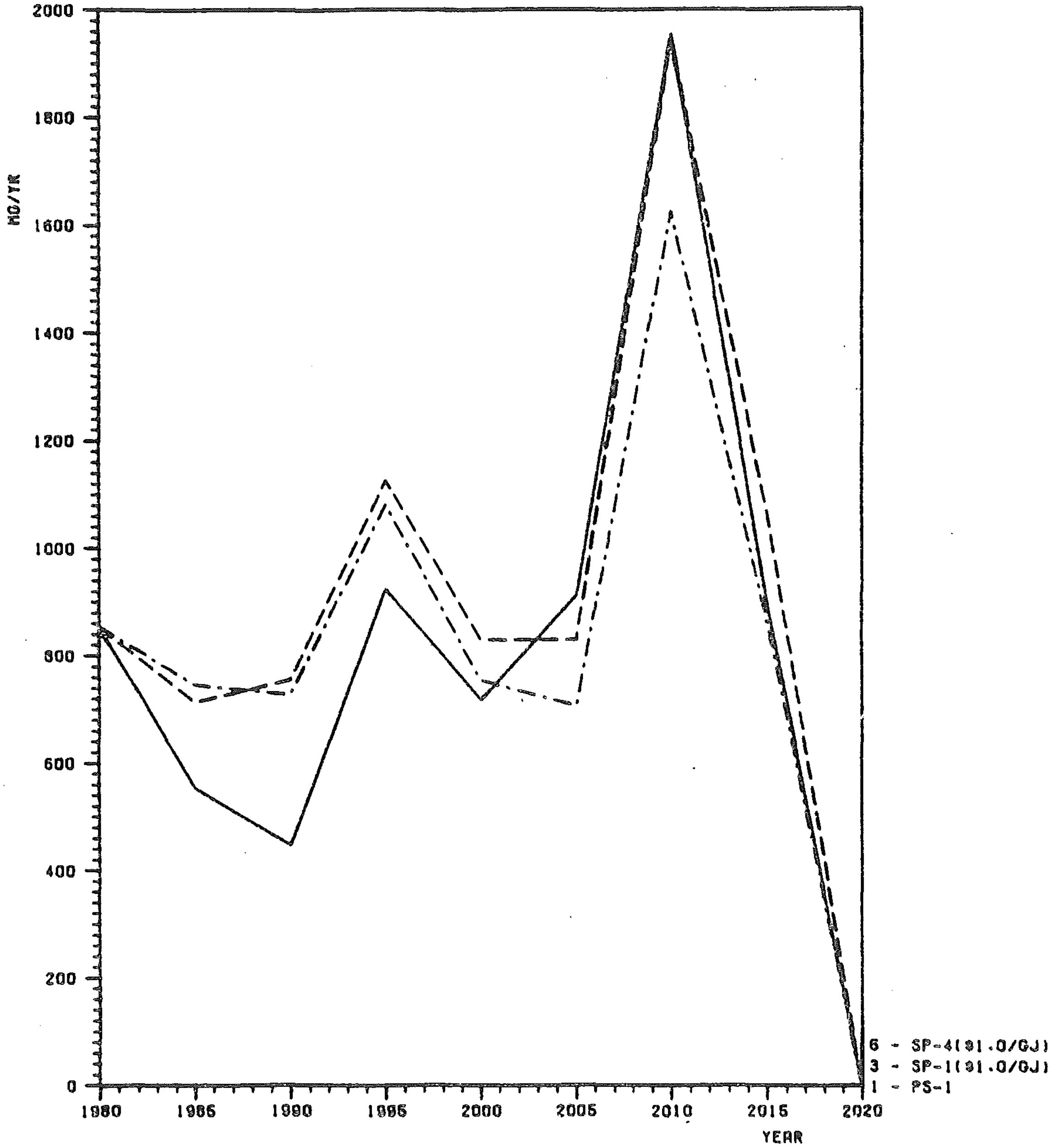

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TABLE 34: PRIMARY ENERGY CONSUMPTION (PJ/YEAR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
3055.2	3546.5	3974.2	4401.3	4886.8	5296.3	5672.2	6028.1	6348.2	1 - PS-1
3055.2	3532.3	3974.3	4421.7	4930.6	5332.5	5693.7	6046.4	6348.7	2 - PS-1 OIL C
3055.2	3520.8	3986.8	4438.4	4949.6	5372.4	5741.6	6143.9	6444.3	3 - SP-1($1.0/GJ)
3055.5	3536.1	3991.4	4439.9	4957.6	5388.3	5769.2	6193.2	6501.8	4 - SP-1
3055.2	3543.0	3973.6	4404.8	4892.5	5289.4	5602.9	5937.3	6279.8	5 - PS-4
3055.2	3524.6	3994.8	4472.4	5013.9	5443.6	5797.8	6199.4	6471.6	6 - SP-4($1.0/GJ)
3059.4	3679.8	4323.9	4884.6	5602.6	6054.4	6791.5	7031.2	7678.8	7 - SP-4/1(LIM FOS 80%)
3055.2	3543.1	3974.3	4386.5	4853.0	5207.3	5477.2	5787.3	6101.1	8 - RP-4
3055.2	3546.5	3974.2	4401.3	4884.9	5264.3	5607.5	5934.6	6248.7	9 - PS-1 COAL C
3055.2	3546.5	3974.8	4397.1	4830.2	5184.8	5507.6	5886.5	6229.7	A - PS-1 LIM NUC

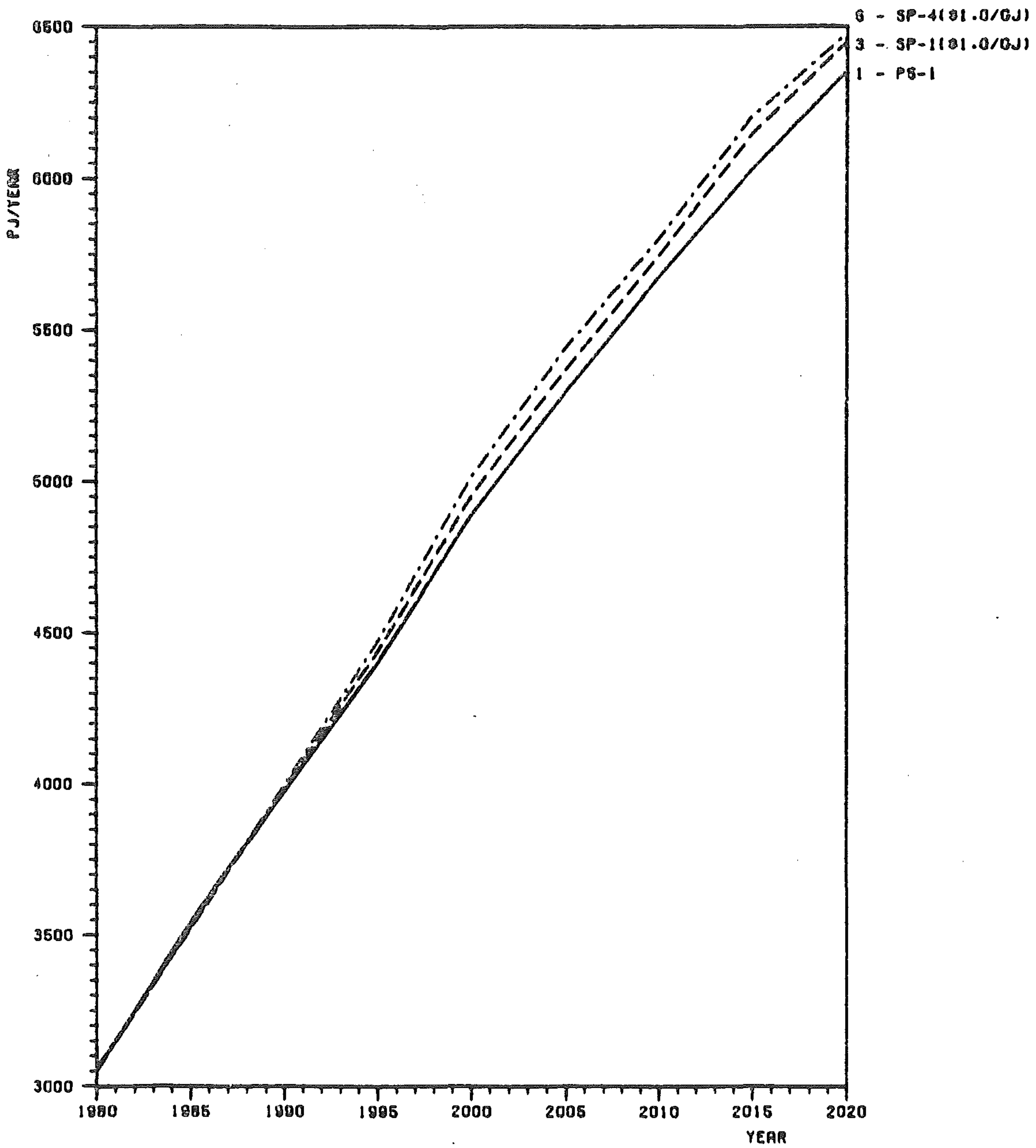

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TABLE 13: PRIMARY ENERGY CONTRIBUTION OF SOLID FUELS (PJ/Y)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
515.4	742.1	975.5	1173.2	1353.7	1623.6	1883.3	2066.6	2183.2	1 - PS-1
515.4	742.1	975.5	1192.7	1426.5	1698.7	1969.7	2109.7	2183.1	2 - PS-1 OIL C
515.4	742.1	975.2	1203.5	1473.4	1796.4	2122.8	2265.3	2356.7	3 - SP-1($1.0/GJ)
515.4	742.1	975.6	1203.8	1474.7	1796.5	2112.3	2243.3	2335.7	4 - SP-1
515.4	742.1	975.6	1177.1	1367.8	1598.6	1813.8	1873.3	1973.1	5 - PS-4
515.4	742.1	984.8	1288.2	1631.7	1965.5	2290.2	2439.0	2512.7	6 - SP-4($1.0/GJ)
515.4	595.0	530.0	577.8	625.6	661.1	614.1	651.4	788.6	7 - SP-4/1(LIM FOS 30%)
515.4	742.1	975.5	1177.1	1367.6	1598.4	1797.1	1969.3	2062.2	8 - RP-4
515.4	742.1	975.5	1173.2	1353.7	1539.8	1677.7	1778.3	1746.7	9 - PS-1 COAL C
515.4	742.1	975.5	1214.8	1473.4	1879.7	2249.4	2886.3	3456.8	A - PS-1 LIM NUC

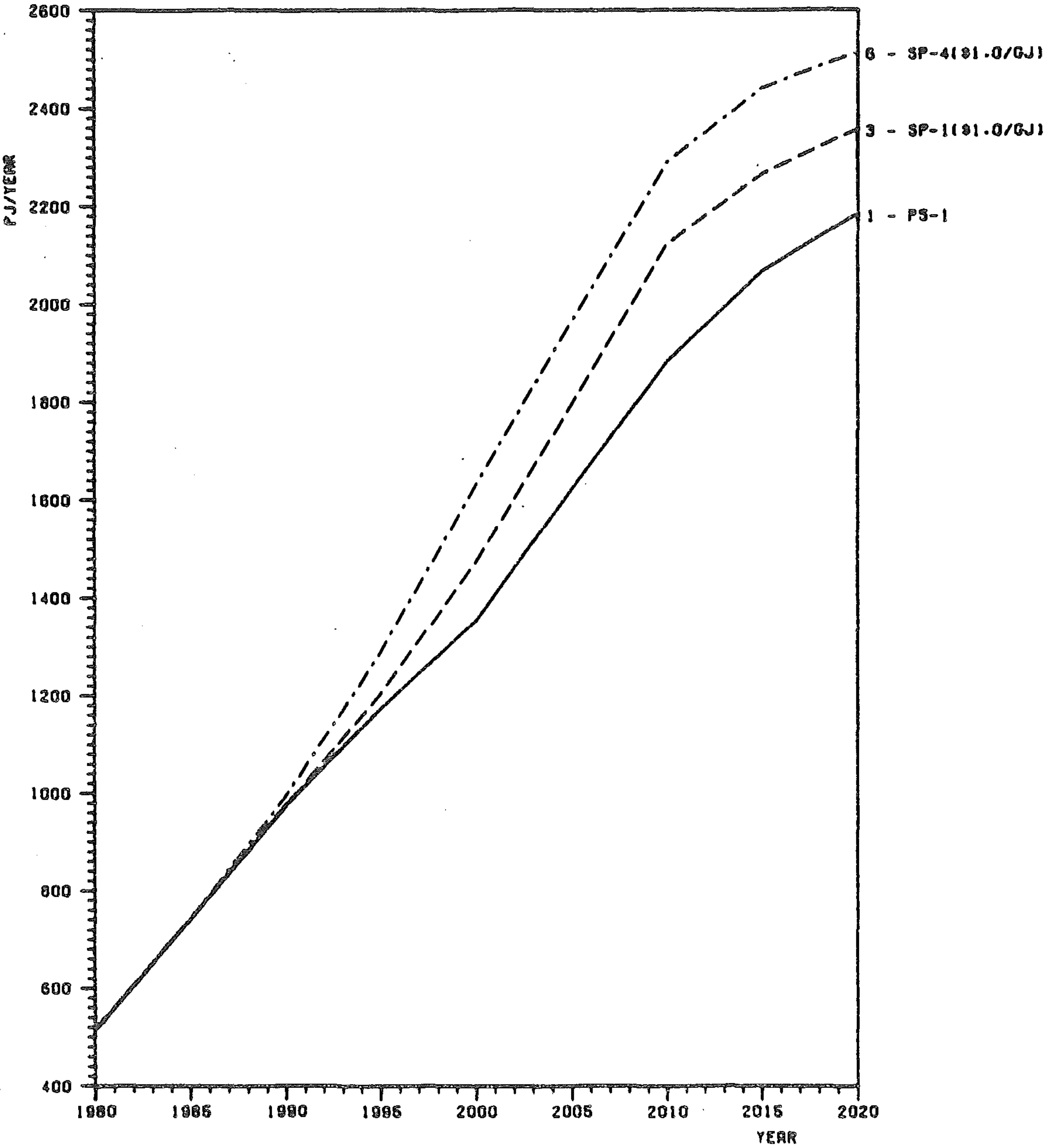

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TABLE 14: PRIMARY ENERGY CONTRIBUTION OF LIQUID FUELS(PJ/Y)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
1969.0	1880.5	1863.2	1916.8	1823.3	1689.6	1546.2	1560.6	1571.7	1 - PS-1
1969.0	1866.3	1833.0	1798.8	1666.8	1600.1	1512.7	1531.1	1571.7	2 - PS-1 OIL C
1969.0	1852.9	1769.9	1731.6	1654.2	1573.8	1468.2	1471.6	1492.4	3 - SP-1($1.0/GJ)
1969.0	1769.0	1740.3	1731.3	1652.6	1570.6	1463.0	1462.3	1476.8	4 - SP-1
1969.0	1875.6	1864.4	1911.8	1818.5	1682.8	1588.2	1633.2	1620.8	5 - PS-4
1969.0	1855.3	1748.4	1692.6	1589.9	1480.0	1354.6	1347.1	1358.3	6 - SP-4($1.0/GJ)
1956.4	1756.4	1876.1	1893.5	1927.4	1948.4	1879.1	1879.0	1738.7	7 - SP-4/1(LIM FOS 80%)
1969.0	1868.8	1849.8	1922.0	1806.9	1667.5	1584.7	1569.4	1561.8	8 - RP-4
1969.0	1880.5	1863.2	1916.8	1847.6	1750.1	1632.0	1694.4	1763.6	9 - PS-1 COAL C
1969.0	1880.5	1865.3	1881.7	1849.4	1700.6	1576.8	1548.9	1578.0	A - PS-1 LIM NUC

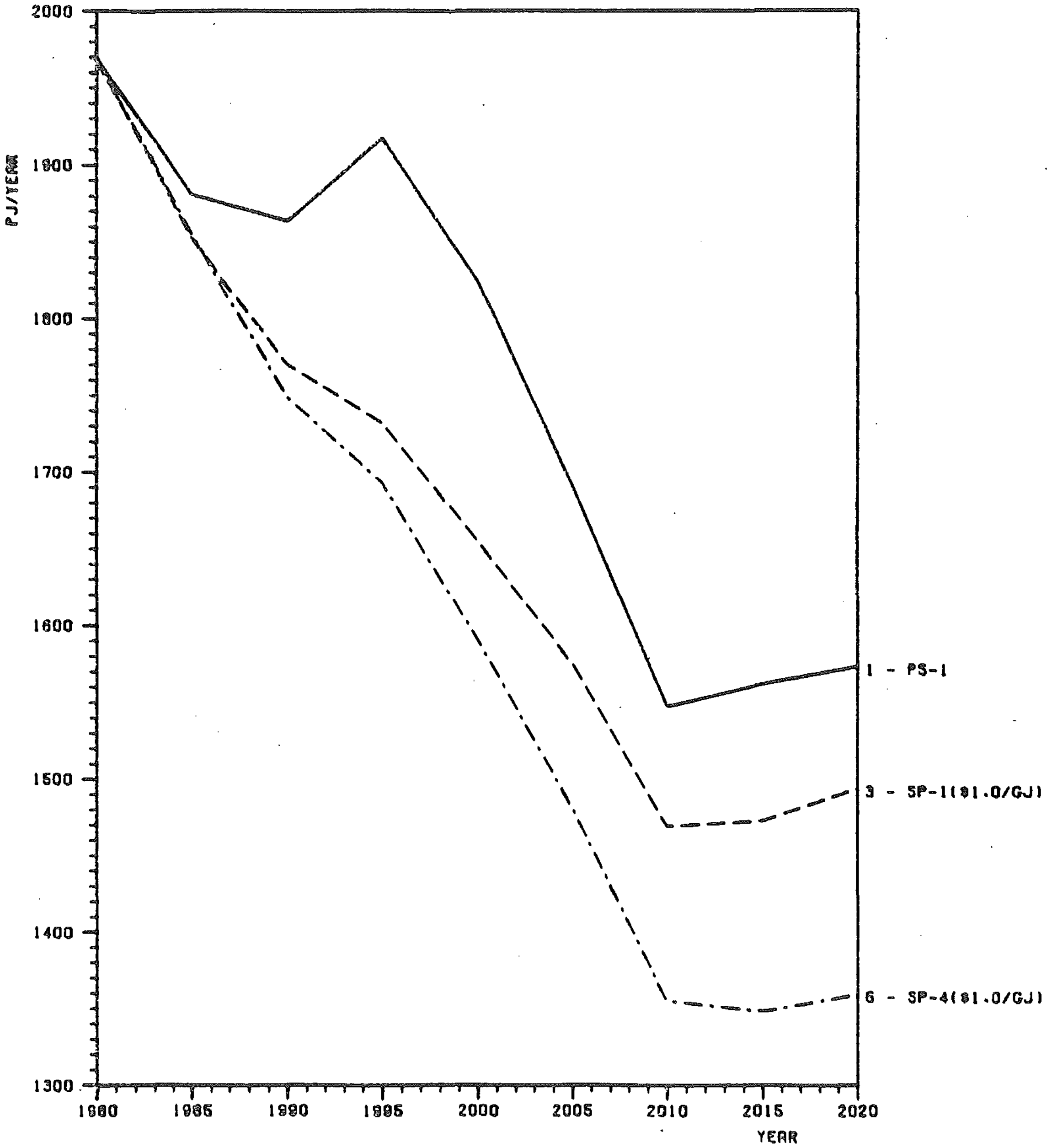

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TABLE 15: PRIMARY ENERGY CONTRIBUTION OF GAS (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
120.3	180.3	180.7	138.9	81.5	52.4	0.0	0.0	0.0	1 - PS-1
120.3	180.3	211.0	209.7	139.9	60.7	0.0	0.0	0.0	2 - PS-1 OIL C
120.3	180.3	211.0	206.3	124.8	29.1	0.0	0.0	0.0	3 - SP-1($1.0/GJ)
120.3	180.3	211.0	206.3	124.8	29.1	0.0	0.0	0.0	4 - SP-1
120.3	180.3	177.5	119.0	41.9	0.0	0.0	0.0	0.0	5 - PS-4
120.3	180.3	205.0	174.9	59.9	0.0	0.0	0.0	0.0	6 - SP-4($1.0/GJ)
120.3	180.3	76.2	0.0	0.0	0.0	0.0	0.0	0.0	7 - SP-4/1(LIM FOS 80%)
120.3	180.3	174.7	110.5	40.9	0.0	0.0	0.0	0.0	8 - RP-4
120.3	180.3	180.7	138.9	55.4	40.7	20.6	0.0	0.0	9 - PS-1 COAL C
120.3	180.3	179.1	155.8	139.0	199.0	287.3	232.4	142.3	A - PS-1 LIM NUC

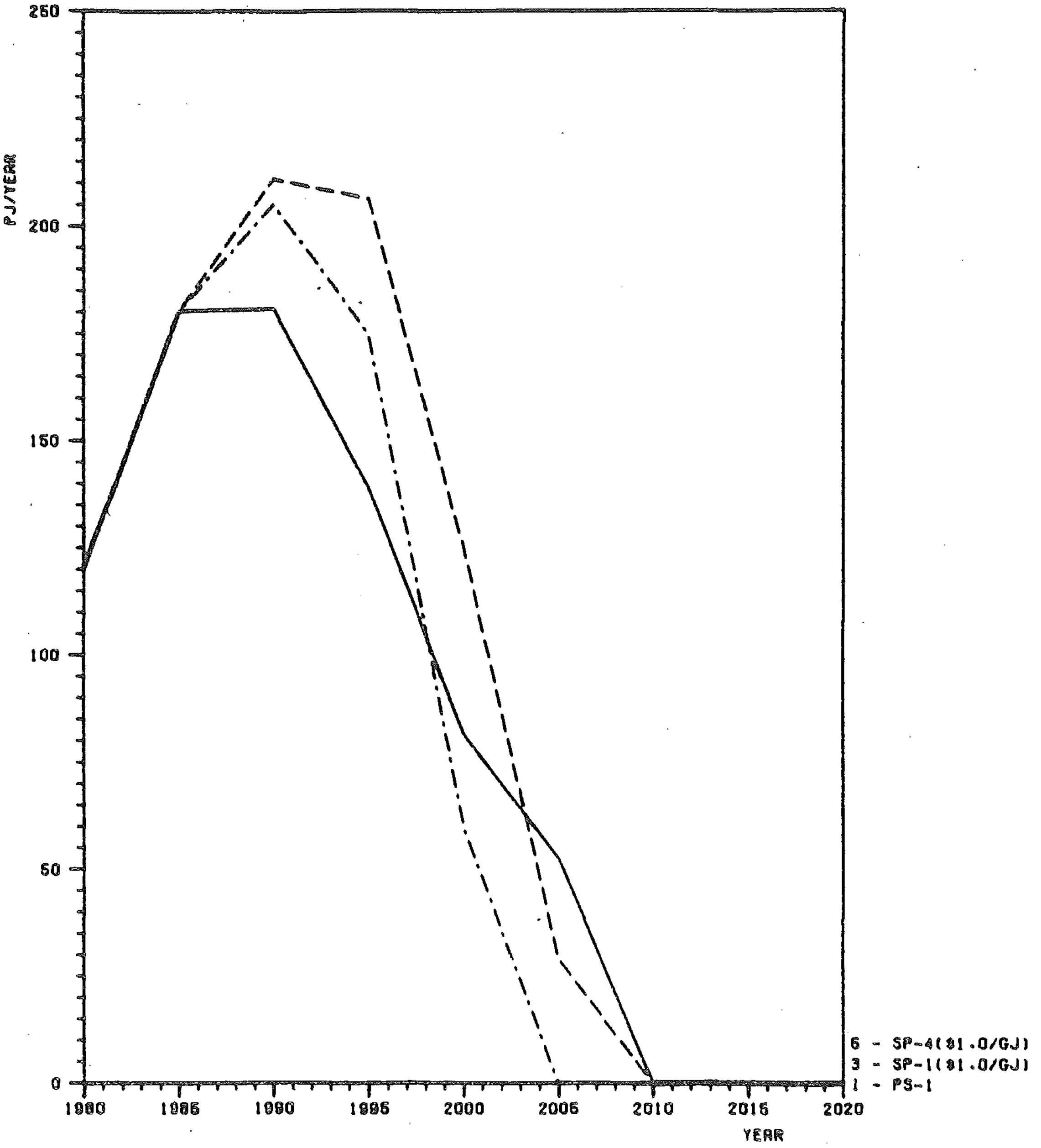

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TABLE 16: PRIMARY ENERGY CONTRIBUTION OF NUCLEAR (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
124.5	404.7	607.0	774.1	1208.6	1490.7	1797.4	1934.5	2125.4	1 - PS-1
124.5	404.7	607.0	821.0	1262.8	1537.5	1765.1	1940.7	2126.1	2 - PS-1 OIL C
124.5	404.7	682.0	904.8	1262.8	1537.4	1706.8	1946.5	2129.0	3 - SP-1($1.0/GJ)
124.8	506.0	720.5	906.3	1290.5	1654.8	1749.3	2024.3	2220.4	4 - SP-1
124.5	404.7	607.0	795.1	1239.1	1558.0	1746.6	1955.7	2211.4	5 - PS-4
124.5	404.7	697.5	923.2	1317.9	1561.6	1708.1	1950.4	2132.2	6 - SP-4($1.0/GJ)
141.4	813.2	1507.8	1939.4	2722.8	3096.0	3960.7	4014.7	4598.5	7 - SP-4/1(LIM FOS 80%)
124.5	404.7	607.0	745.7	1181.5	1467.5	1577.5	1895.2	1929.8	8 - RP-4
124.5	404.7	607.0	774.1	1208.6	1493.8	1833.4	1992.2	2263.7	9 - PS-1 COAL C
124.5	404.7	607.0	745.8	953.9	985.4	948.1	751.5	578.1	A - PS-1 LIM NUC

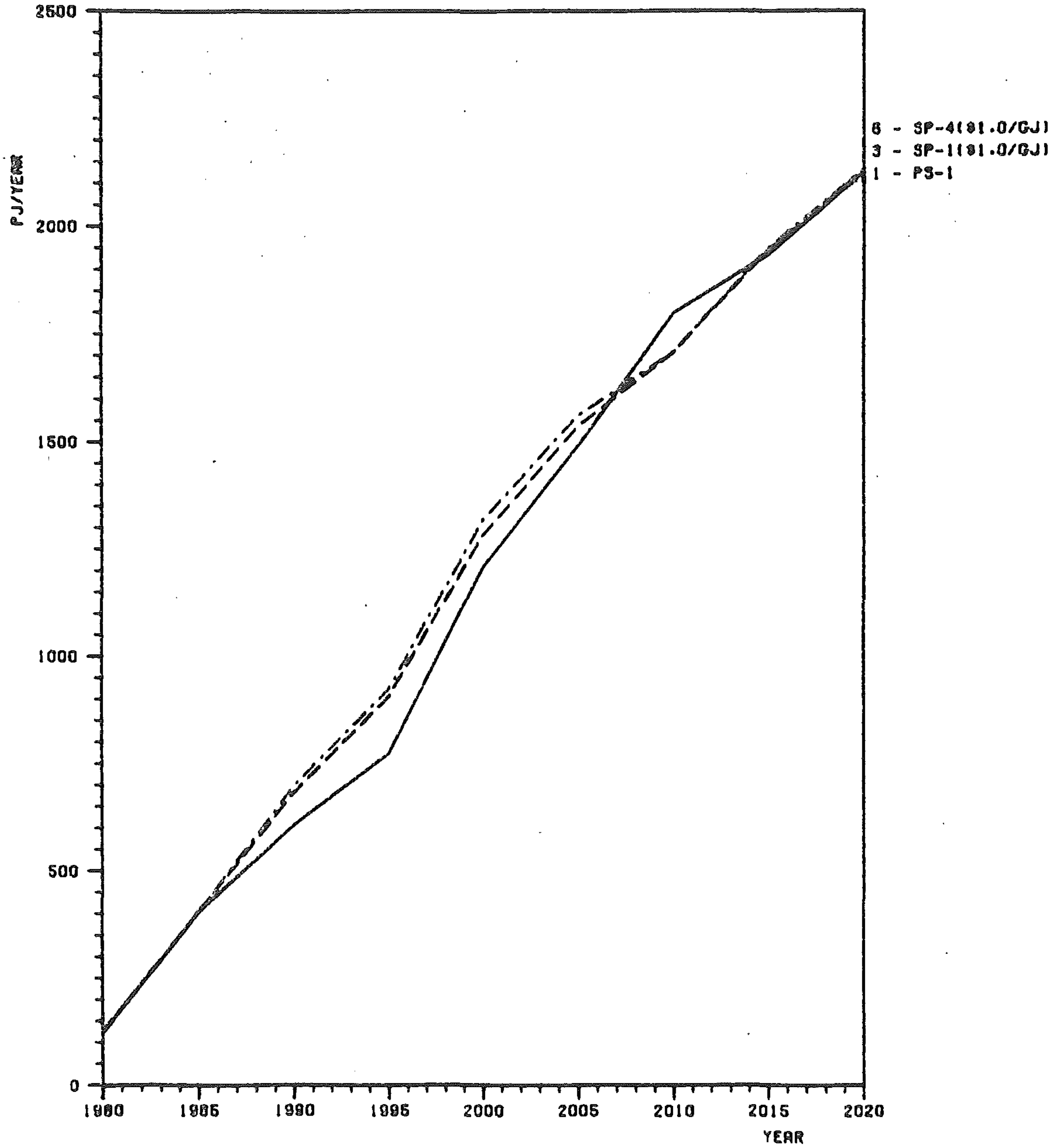

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TABLE 17: PRIMARY ENERGY CONTRIBUTION OF RENEWABLES (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
326.0	338.9	347.8	398.3	419.7	440.0	445.3	466.5	467.9	1 - PS-1
326.0	338.9	347.8	399.4	414.4	435.7	446.2	464.9	467.8	2 - PS-1 OIL C
326.0	340.8	347.8	392.2	414.4	435.7	443.7	461.4	467.2	3 - SP-1(91.0/GJ)
326.0	338.7	344.0	392.3	414.9	437.2	444.7	463.4	468.8	4 - SP-1
326.0	340.4	349.1	401.9	425.2	449.2	454.4	475.1	474.7	5 - PS-4
326.0	342.2	349.1	393.5	414.5	436.4	444.9	462.0	468.4	6 - SP-4(91.0/GJ)
326.0	334.9	333.8	373.9	326.8	348.1	337.6	486.1	553.0	7 - SP-4/1(LIM FOS 80%)
326.0	347.1	367.3	430.2	466.1	484.0	517.8	553.5	567.3	8 - RP-4
326.0	338.9	347.8	398.3	419.7	440.0	443.8	469.8	474.8	9 - PS-1 COAL C
326.0	338.9	347.8	398.9	414.6	440.1	447.1	467.4	474.5	A - PS-1 LIM NUC

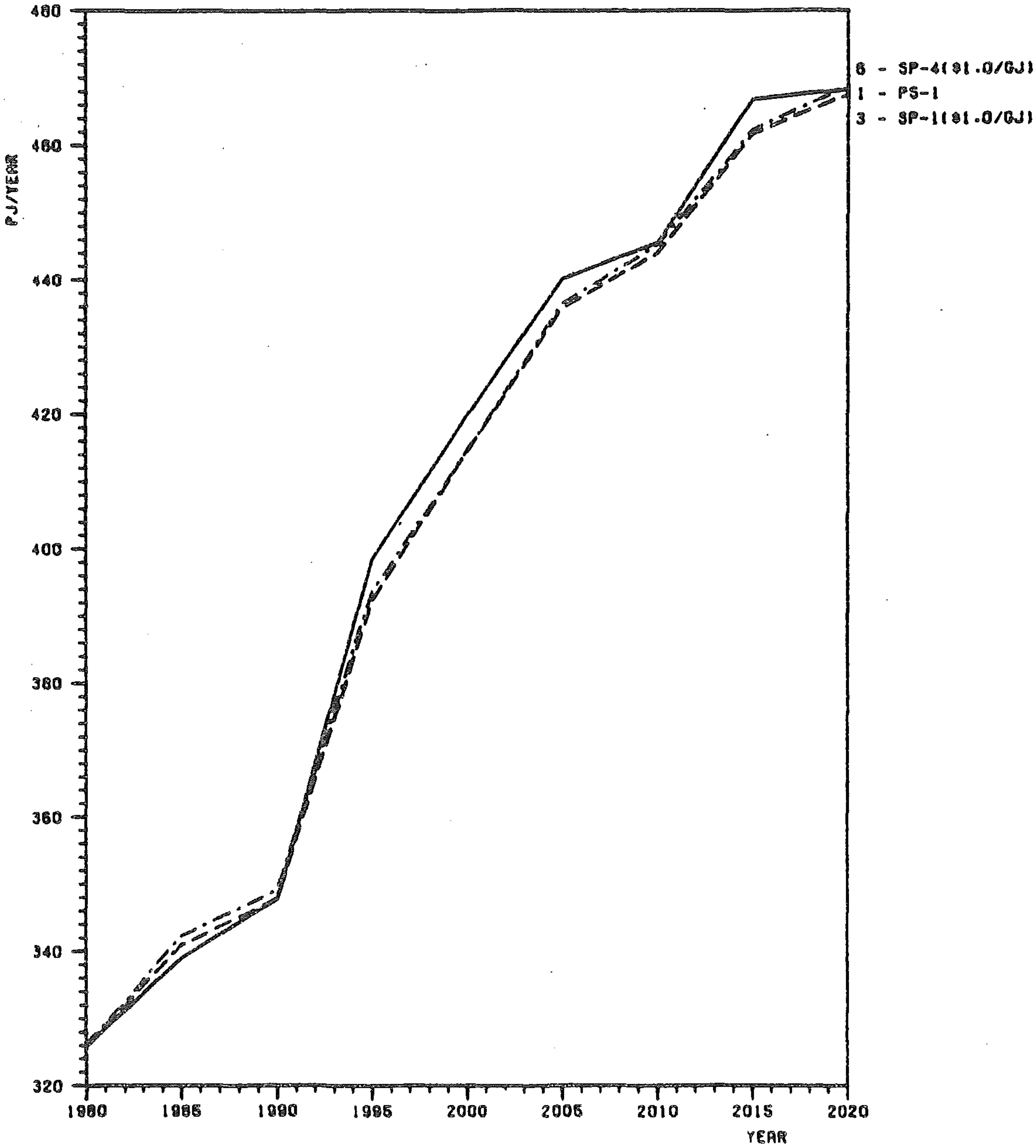

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TABLE 18: ELECTRICITY BUSBAR OUTPUT (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
345.9	427.8	498.7	562.1	651.8	703.9	751.2	803.9	854.3	1 - PS-1
345.9	422.3	496.1	562.5	651.8	703.9	751.2	803.9	854.3	2 - PS-1 OIL C
345.9	421.6	496.2	562.2	651.8	703.9	750.9	803.9	854.5	3 - SP-1($1.0/GJ)
346.1	421.7	496.2	562.8	655.0	710.3	761.6	822.6	866.1	4 - SP-1
345.9	426.3	501.0	567.5	657.5	710.9	760.1	814.7	862.0	5 - PS-4
345.9	422.9	498.0	566.3	657.5	711.0	760.2	810.4	861.8	6 - SP-4($1.0/GJ)
346.6	466.3	566.0	809.0	1015.6	1140.1	1436.7	1509.1	1716.5	7 - SP-4/1(LIM FOS 80%)
345.9	423.3	498.2	564.4	657.1	710.3	768.0	819.9	870.1	8 - RP-4
345.9	427.8	498.7	562.1	651.8	704.0	751.2	804.5	855.4	9 - PS-1 COAL C
345.9	427.8	499.6	565.8	651.6	703.5	749.7	803.5	854.4	A - PS-1 LIM NUC

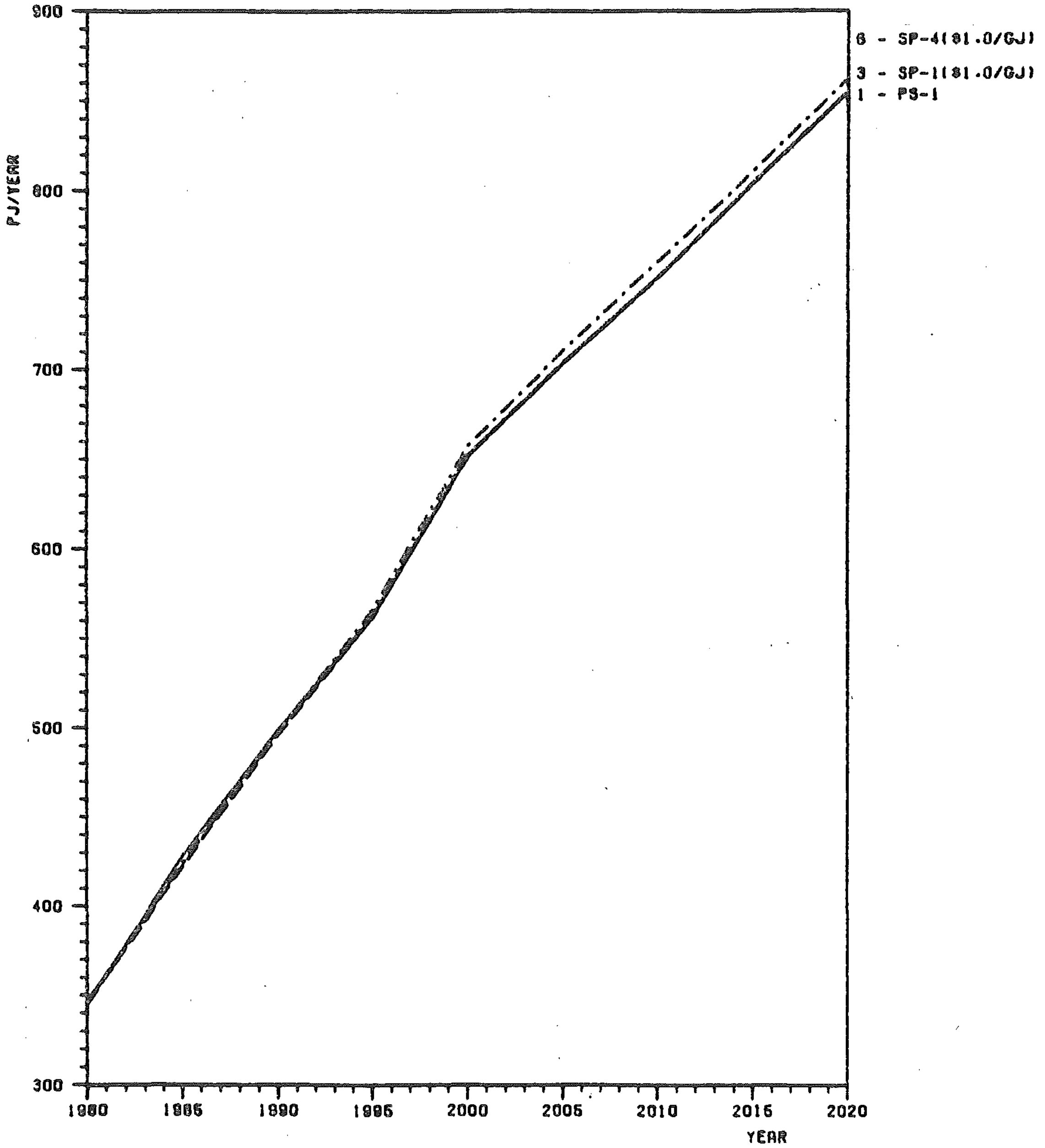

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TABLE 21: DIESEL FOR ROAD TRANSPORT (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
232.0	266.8	299.0	327.1	336.2	360.0	370.0	371.7	381.6	1 - PS-1
232.0	266.8	299.0	327.1	336.2	360.0	370.0	371.7	381.6	2 - PS-1 OIL C
232.0	266.8	299.0	327.1	336.2	360.0	370.0	371.7	381.6	3 - SP-1($1.0/GJ)
232.0	266.8	298.0	326.8	334.7	357.0	366.0	362.7	366.8	4 - SP-1
232.0	265.8	294.8	318.6	325.6	347.5	355.0	355.7	372.4	5 - PS-4
232.0	266.8	294.8	318.6	325.6	347.5	355.0	355.7	366.8	6 - SP-4($1.0/GJ)
232.0	266.8	294.3	315.6	320.6	337.5	340.0	336.5	366.8	7 - SP-4/1(LIM FOS 80%)
232.0	265.8	294.8	318.6	325.8	347.5	355.0	355.7	366.8	8 - RP-4
232.0	266.8	299.0	327.1	336.2	360.0	370.0	371.7	381.8	9 - PS-1 COAL C
232.0	266.8	299.0	327.1	336.2	360.0	371.9	371.7	381.8	A - PS-1 LIM NUC

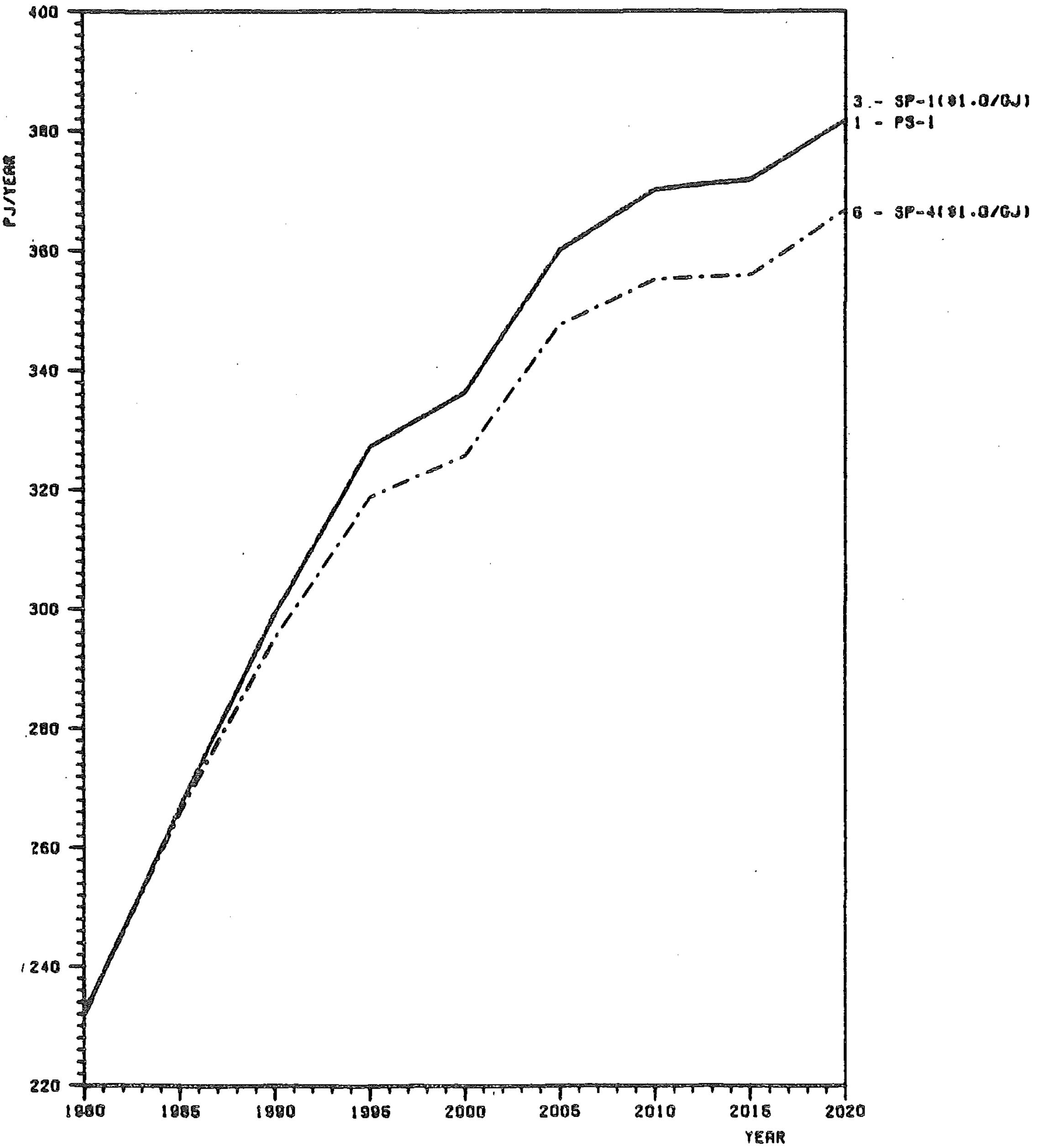

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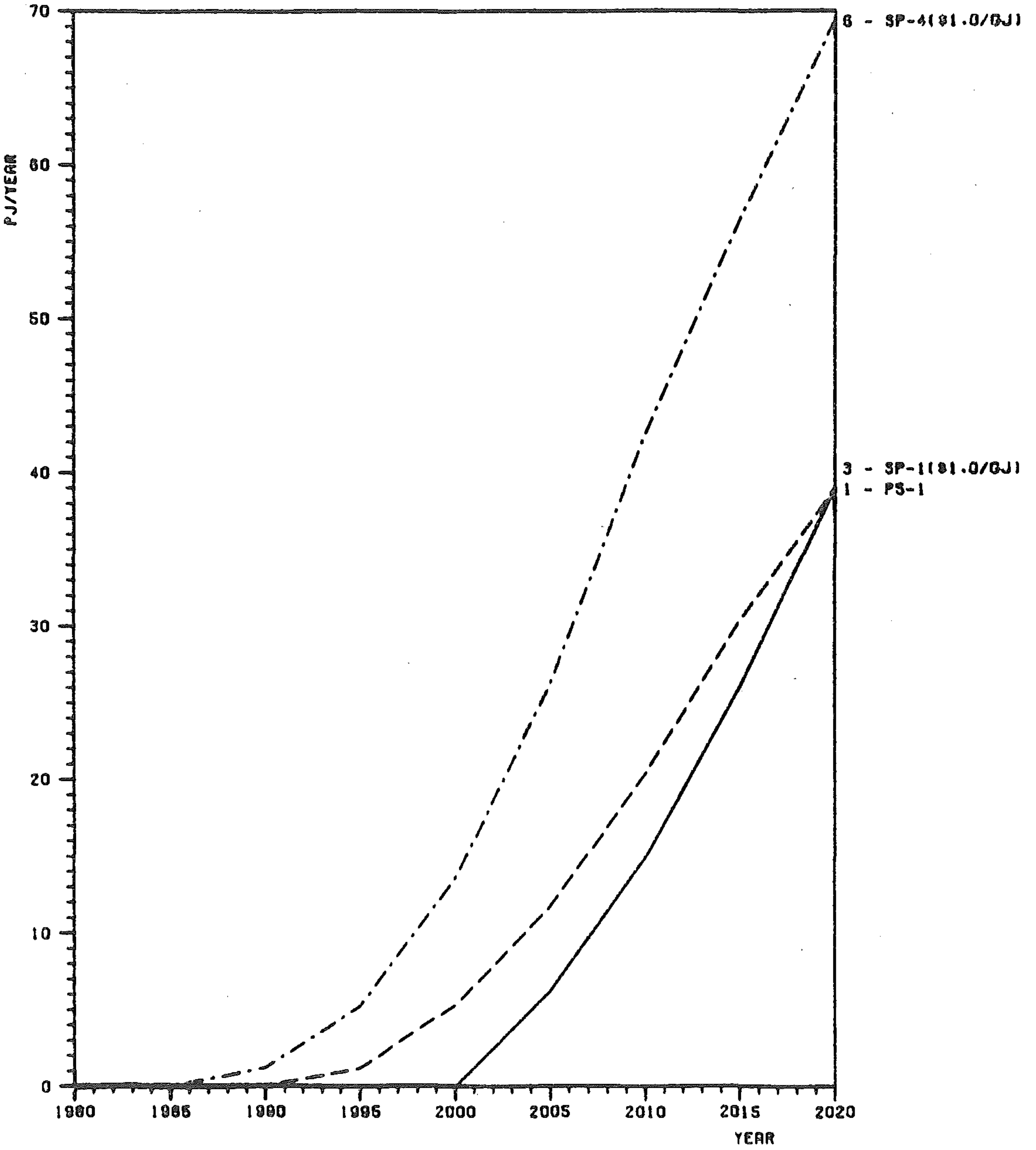
TABLE 22: METHANOL FOR ROAD TRANSPORT (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	0.0	0.0	0.0	0.0	6.2	14.9	26.0	39.0	1 - PS-1
0.0	0.0	0.0	1.2	5.3	11.7	20.4	30.3	39.0	2 - PS-1 OIL C
0.0	0.0	0.0	1.2	5.3	11.7	20.4	30.3	39.0	3 - SP-1($1.0/GJ)
0.0	0.0	0.0	1.2	5.3	11.7	20.4	30.3	39.0	4 - SP-1
0.0	0.0	0.0	0.0	0.0	12.5	29.7	47.7	69.4	5 - PS-4
0.0	0.0	1.2	5.2	13.5	26.2	42.5	56.4	69.4	6 - SP-4($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7 - SP-4/1(LIM FOS 80%)
0.0	0.0	0.0	0.0	0.0	12.5	29.7	47.7	69.4	8 - RP-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9 - PS-1 COAL C
0.0	0.0	0.0	0.0	0.0	6.2	14.9	26.0	39.0	A - PS-1 LIM NUC



5.4 Impacts of New Technologies

5.4.1 Coal Liquefaction

This group of technologies comprises the following:

SOF Hard coal liquefaction hydrogenation

SOG Hard coal liquefaction Fischer-Tropsch

SO4 Hard coal to methanol

The group is competitive in all the scenarios, except PS-1/COAL C and SP-4/LIM FOS. Since these two scenarios assume higher imported coal prices and limitation on fossil energy use respectively, (both conditions making coal less attractive to the model), it is possible to deduce that these technologies are only competitive if both coal availability is not restricted and the imported coal price evolution is that shown in Figure 7. This price schedule is used in all scenarios (except PS-1/COAL C).

When these technologies are individually analysed, the Fischer-Tropsch process is less competitive than the other two. Tables 7, 8 and 9 show the individual activity of these technologies, that is, the amount of oil-derived fuels which they can substitute. They also show the date of first commercial availability and when they become competitive. Table 6 shows the bounds and date of implementation of all technologies considered in this study. For example, it is possible to observe in Table 7 that the technology SOF appears in the PS-1 scenario, and does not do so in the PS-4 scenario. This is because there are more competitive technologies now with higher implementation levels than in the PS-1 scenario. The graph on page 97 shows the evolution of the aggregated values of those three technologies.

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: S0F

TECHNOLOGY: HARD COAL LIQUEFACTION - HYDROGENATION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	1015	2020	SCENARIO
–	–	–	0	0	42	100	158	216	PS-1
–	–	–	11	40	82	139	187	216	PS-1/OIL C
–	–	–	11	40	82	139	187	216	SP-1/($1.0/GJ)
–	–	–	11	40	82	139	187	216	SP-1
–	–	0	0	0	0	0	0	79	PS-4
–	–	11	37	79	137	200	253	289	SP-4/1($1.0/GJ)
–	–	0	0	0	0	0	0	0	SP-4/LIM FOS
–	–	0	0	0	0	0	79	153	RP-4
–	–	–	0	0	0	0	0	0	PS-1/COAL C
–	–	–	0	29	71	129	187	216	PS-1/LIM NUC

TABLE 7

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: S0G

TECHNOLOGY: HARD COAL LIQUEFACTION. FISCHER - TROPSCH (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
–	–	–	0	0	0	0	0	0	PS-1
–	–	–	0	0	0	0	0	0	PS-1/OIL C
–	–	–	7	26	53	90	120	139	SP-1/($1.0/GJ)
–	–	–	7	26	53	90	120	139	SP-1
–	–	0	0	0	0	0	0	0	PS-4
–	–	0	22	59	105	152	185	204	SP-4/($1.0/GJ)
–	–	0	0	0	0	0	0	0	SP-4/LIM FOS
–	–	0	0	0	0	0	0	0	RP-4
–	–	–	0	0	0	0	0	0	PS-1/COAL C
–	–	–	0	0	0	0	0	0	PS-1/LIM NUC

TABLE 8

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: S04

TECHNOLOGY: HARD COAL TO METHANOL (PJ/YR)

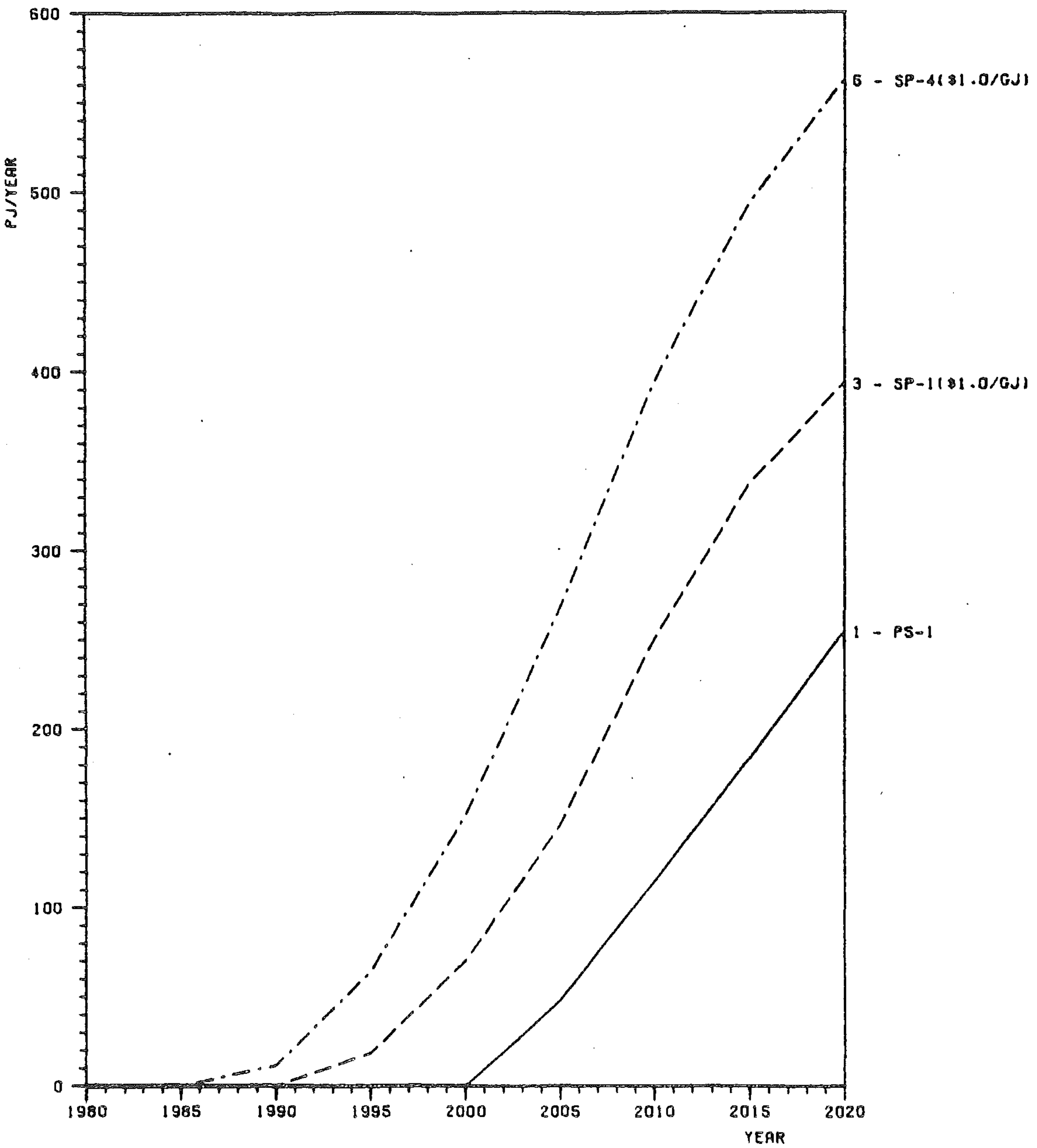
1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
–	–	–	0	0	7	15	26	39	PS-1
–	–	–	1	5	12	20	30	39	PS-1/OIL C
–	–	–	1	5	12	20	30	39	SP-1/($1.0/GJ)
–	–	–	1	5	12	20	30	39	SP-1
–	–	0	0	0	13	30	48	69	PS-4
–	–	1	5	14	26	43	56	69	SP-4/($1.0/GJ)
–	–	0	0	0	0	0	0	0	SP-4/LIM FOS
–	–	0	0	0	13	30	48	69	RP-4
–	–	–	0	0	0	0	0	0	PS-1/COAL C
–	–	–	0	0	6	15	26	39	PS-1/LIM NUC

TABLE 9

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 1: COAL LIQUEFACTION OUTPUT (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
0.0	0.0	0.0	0.0	0.0	48.3	114.8	183.8	254.7	1	- PS-1
0.0	0.0	0.0	11.7	44.8	93.2	159.8	217.0	254.7	2	- PS-1/OIL C
0.0	0.0	0.0	18.6	70.3	146.4	250.1	337.4	393.6	3	- SP-1($1.0/GJ)
0.0	0.0	0.0	18.6	70.3	146.4	250.1	337.4	393.6	4	- SP-1
0.0	0.0	0.0	0.0	0.0	12.5	29.7	47.7	148.3	5	- PS-4
0.0	0.0	11.7	64.1	151.5	268.4	394.1	494.1	562.4	6	- SP-4($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	- SP-4/1(80% LIM FOS)
0.0	0.0	0.0	0.0	0.0	12.5	29.7	126.6	222.1	8	- RP-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9	- PS-1/COAL C
0.0	0.0	0.0	0.0	28.9	77.2	143.8	212.7	254.7	A	- PS-1/LIM NUC



5.4.2 High Quality Gasification

Technologies:

S01 Hard coal Lurgi high BTU gasification

S0A Hard coal nuclear hydrogasification

S0B Hard coal nuclear hydro-steam gasification

S11 Brown coal Lurgi high BTU gasification

S1A Brown coal nuclear hydrogasification

This group appears in all scenarios and is generally quite competitive, although there are differences in the competitiveness of each technology. The Lurgi hard coal gasification process (S01) does not appear in any scenario, and in general the same process for brown coal (S11) only appears between the years 1995 and 2005, showing small contributions. But the remaining three technologies (S0A, S0B and S1A), which are combined with high temperature reactors, are very competitive in all scenarios. In fact, these technologies are the most competitive among those producing synthetic fuels from coal. This applies also to the PS-1/COAL C and SP-4/LIM FOS scenarios. Tables 10, 11, 12 and 13 show the activity of these technologies and the dates on which they become competitive; the graph on page 103 shows the aggregated values of this group of technologies.

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: S0A

TECHNOLOGY: HARD COAL NUCLEAR HYDROGASIFICATION (PJ/JR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
-	-	-	14	52	107	183	245	283	PS-1
-	-	-	14	52	107	183	245	283	PS-1/OIL C
-	-	-	14	52	107	183	245	283	SP-1/($1.0/GJ)
-	-	-	14	52	107	183	245	283	SP-1
-	-	-	21	69	138	227	296	338	PS-4
-	-	-	21	69	138	227	296	338	SP-4/($1.0/GJ)
-	-	-	21	69	138	227	296	338	SP-4/LIM FOS
-	-	-	21	69	138	227	296	338	RP-4
-	-	-	14	52	107	183	245	283	PS-1/COAL C
-	-	-	0	0	0	0	0	0	PS-1/LIM NUC

TABLE 10

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: S0B

TECHNOLOGY: HARD COAL NUCLEAR STEAM GASIFICATION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	1015	2020	SCENARIO
–	–	–	14	54	111	189	185	146	PS-1
–	–	–	14	54	111	189	175	146	PS-1/OIL C
–	–	–	14	54	111	160	146	107	SP-1/($1.0/GJ)
–	–	–	14	54	111	155	141	101	SP-1
–	–	–	21	71	143	214	193	143	PS-4
–	–	–	21	71	71	71	50	0	SP-4/($1.0/GJ)
–	–	–	0	0	0	0	222	308	SP-4/LIM FOS
–	–	–	21	71	143	189	169	119	RP-4
–	–	–	14	54	111	189	219	205	PS-1/COAL C
–	–	–	0	0	0	0	0	0	PS-1/LIM NUC

TABLE 11

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: S11

TECHNOLOGY: BROWN COAL LURGI HIGH BTU GASIFICATION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
-	-	0	5	8	8	0	0	0	PS-1
-	-	0	6	8	8	0	0	0	PS-1/OIL C
-	-	0	6	8	8	0	0	0	SP-1/($1.0/GJ)
-	-	0	6	8	8	0	0	0	SP-1
-	0	0	1	0	1	0	0	0	PS-4
-	0	0	1	0	1	0	0	0	SP-4/($1.0/GJ)
-	0	18	45	77	35	0	0	0	SP-4/LIM FOS
-	0	0	1	0	1	0	0	0	RP-4
-	-	0	5	8	5	0	0	0	PS-1/COAL C
-	-	0	13	35	57	0	16	68	PS-1/LIM NUC

TABLE 12

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: S1A

TECHNOLOGY: BROWN COAL NUCLEAR HYDROGASIFICATION (PJ/YR)

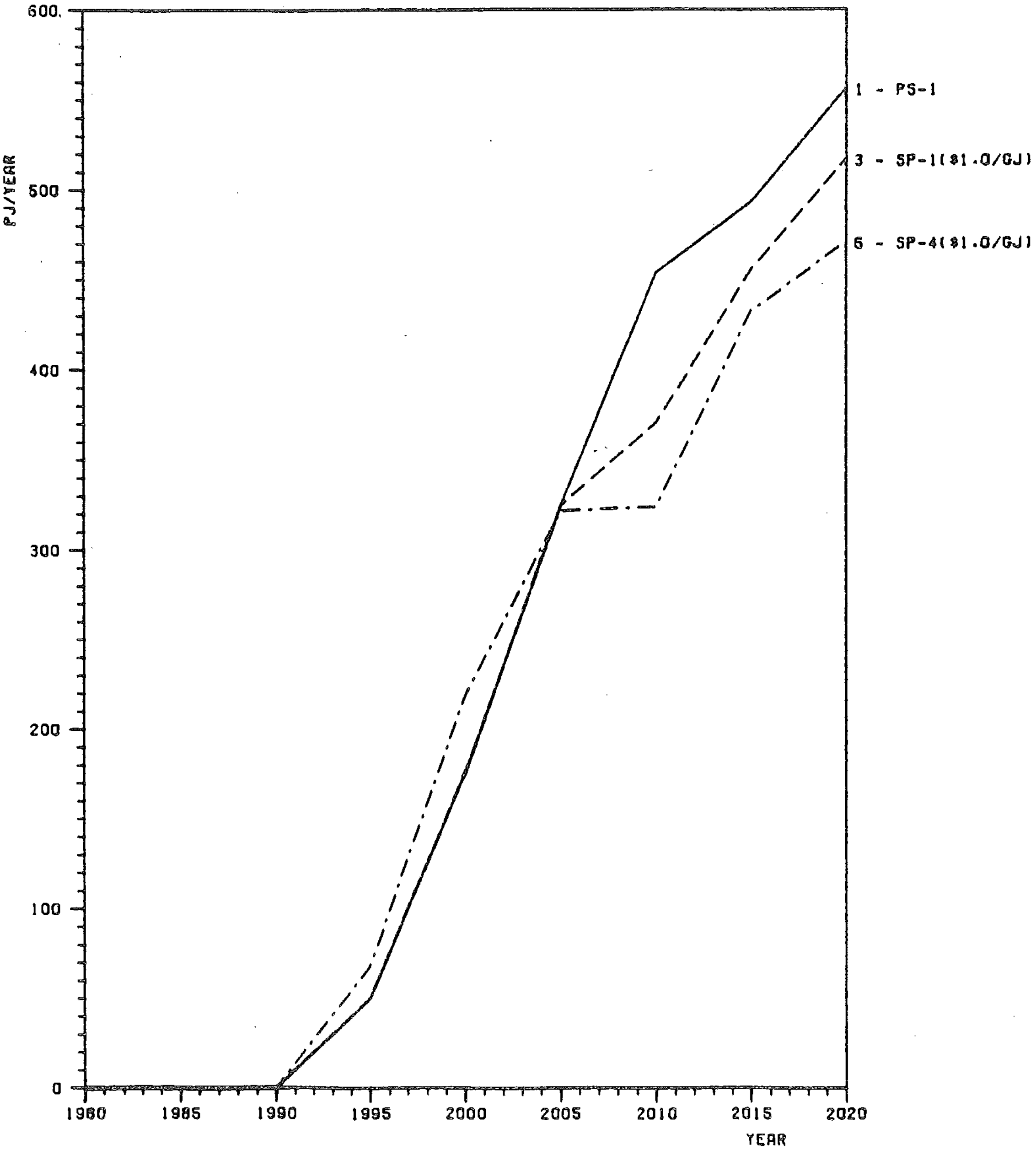
1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
-	-	-	17	62	99	82	63	128	PS-1
-	-	-	17	62	99	60	65	128	PS-1/OIL C
-	-	-	17	62	99	28	65	128	SP-1/($1.0/GJ)
-	-	-	17	62	99	37	82	128	SP-1
-	-	-	25	79	112	24	52	133	PS-4
-	-	-	25	79	111	25	86	133	SP-4($1.0/GJ)
-	-	-	25	83	166	143	153	163	SP-4/LIM FOS
-	-	-	25	79	112	6	63	133	RP-4
-	-	-	17	62	104	104	88	133	PS-1/COAL C
-	-	-	0	0	0	0	0	0	PS-1/LIM NUC

TABLE 13

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 2: COAL HIGH BTU GASIFICATION, OUTPUT (PJ/Y)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	0.0	0.0	50.1	175.6	324.5	454.1	493.2	556.1	1 - PS-1
0.0	0.0	0.0	50.4	175.7	324.5	432.1	484.7	556.2	2 - PS-1/OIL C
0.0	0.0	0.0	50.3	175.7	324.5	370.4	455.7	517.0	3 - SP-1($1.0/GJ)
0.0	0.0	0.0	50.3	175.6	324.5	374.5	467.4	511.6	4 - SP-1
0.0	0.0	0.0	67.7	218.8	392.9	465.5	541.3	613.6	5 - PS-4
0.0	0.0	0.0	67.9	218.8	321.4	323.8	432.7	471.0	6 - SP-4($1.0/GJ)
0.0	0.0	18.4	90.9	229.2	338.6	370.1	671.1	808.3	7 - SP-4/1(80% LIM FOS)
0.0	0.0	0.0	67.7	218.8	393.3	422.3	527.7	589.8	8 - RP-4
0.0	0.0	0.0	50.1	175.6	326.8	476.2	550.9	620.9	9 - PS-1/COAL C
0.0	0.0	0.0	13.3	35.2	57.0	0.0	16.1	68.1	A - PS-1/LIM NUC



5.4.3 Low-Medium BTU Gasification

The group includes two technologies:

S02 Hard coal medium BTU gasification

S12 Brown coal medium BTU gasification

This group is only competitive in the PS-1/LIM NUC scenario, and only during the last three time periods. The following table shows the activity of the group in this scenario.

	PERIOD			
TECHNOLOGY	Earlier Periods	2010	2015	2020
S01	0	48	97	154
S12	0	0	0	0

5.4.4 New non-renewable and non-nuclear technologies for electricity production

This group includes the following technologies:

E06 Hard coal combined cycle power plant

EOE In-situ coal gasification

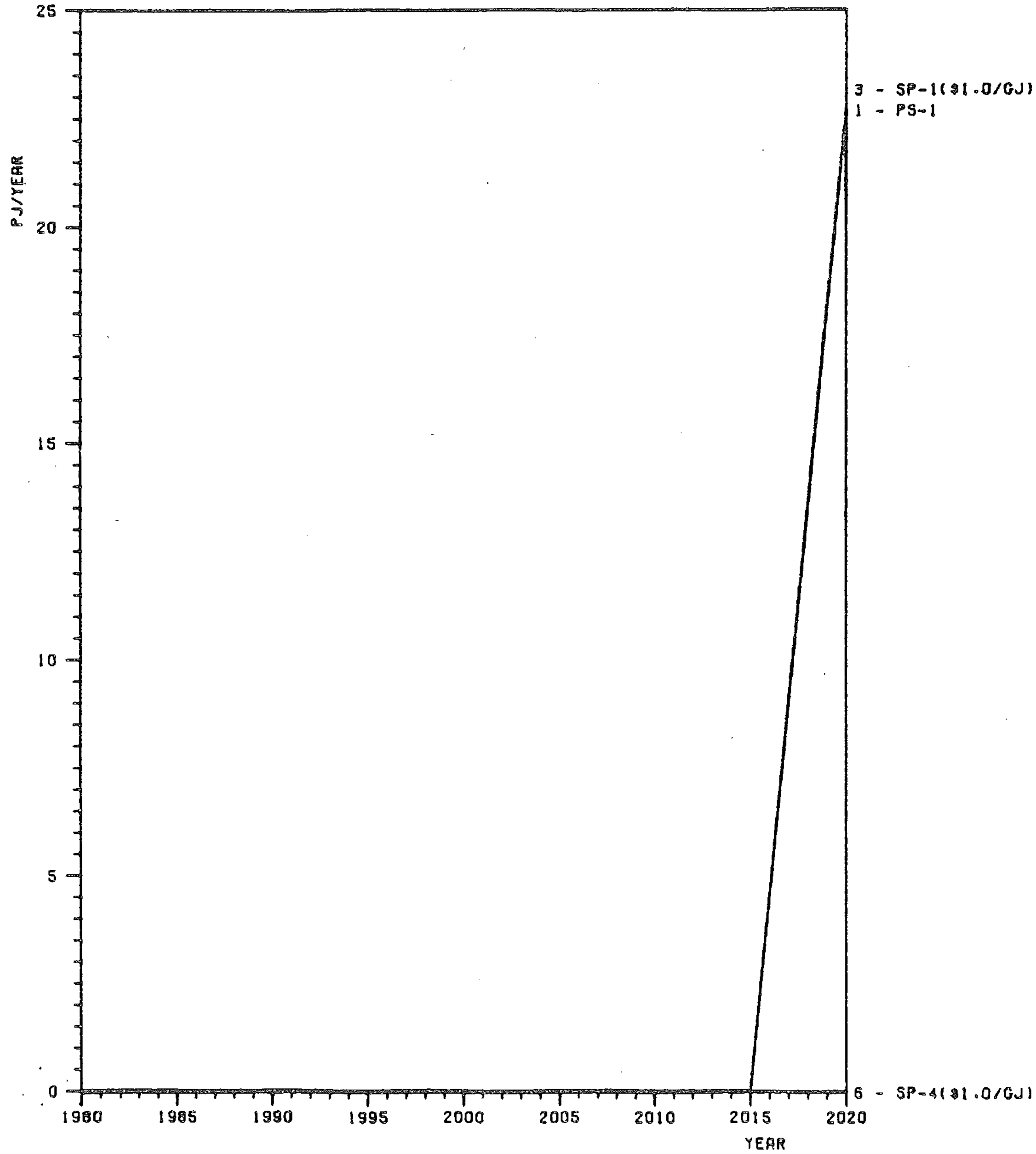
E94 Gas fuel cell

The group shows activity in all the scenarios but with low values. The most competitive of these technologies is in-situ gasification (EOE) mainly in the PS-1/LIM FOS scenario, since the limitation on nuclear energy use forces the model to choose technologies using fossil energy carriers. On the other hand, the gas fuel cell shows the lowest competitiveness. The Figures on pages 105 and 106 show the activity of these three technologies.

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 4: HARD COAL COMBINED CYCLE. ELECTRICITY PROD (PJ/YR)

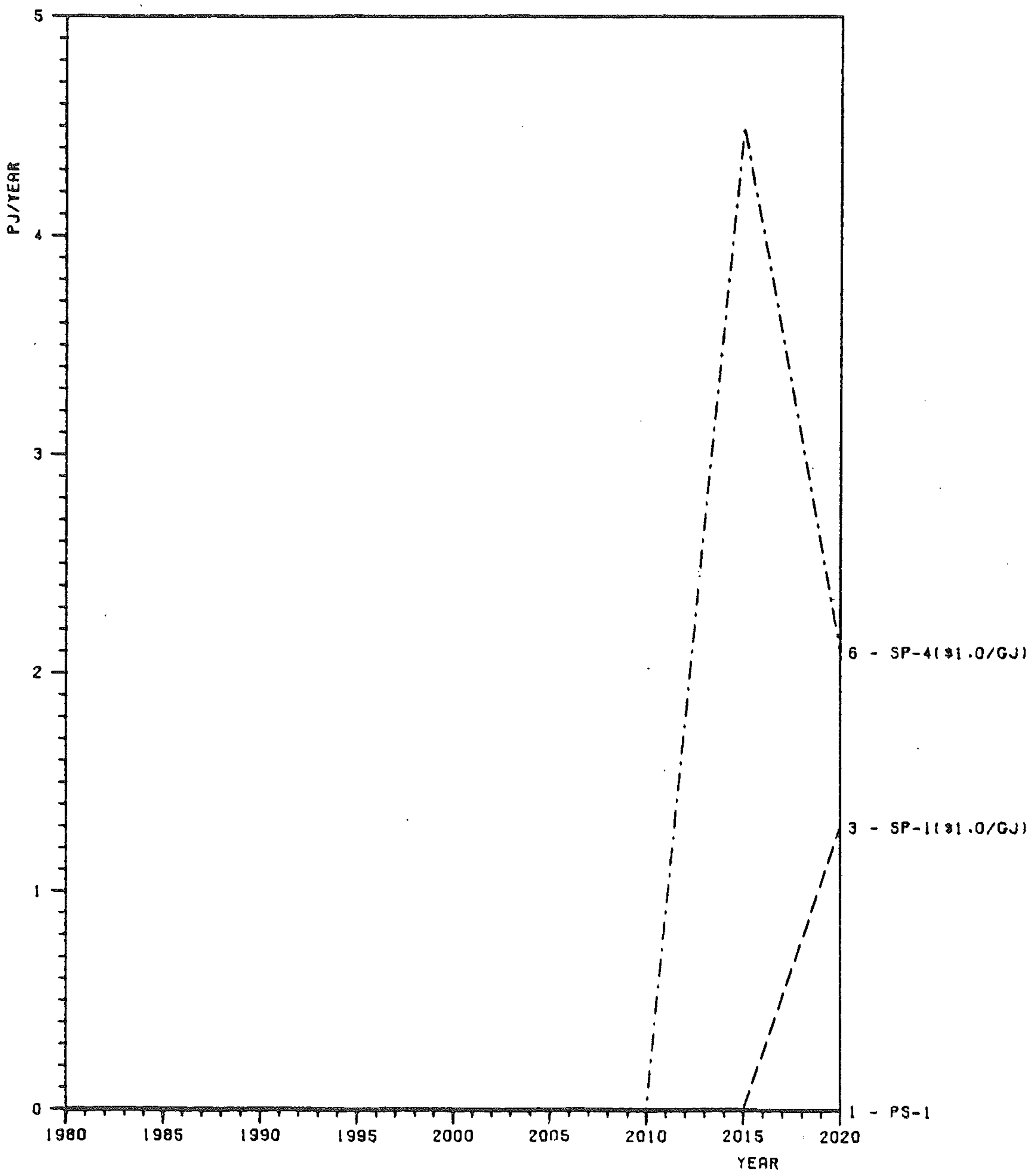
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.7	1 - PS-1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.7	2 - PS-1/OIL C
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.7	3 - SP-1($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.7	4 - SP-1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5 - PS-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6 - SP-4($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7 - SP-4/1(80% LIM FOS)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8 - RP-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9 - PS-1/COAL C
0.0	0.0	0.0	20.4	43.1	65.8	88.5	111.1	113.3	A - PS-1/LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 7: GAS FUEL CELL, ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 - PS-1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2 - PS-1/OIL C
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	3 - SP-1($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.2	4 - SP-1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	5 - PS-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.1	6 - SP-4($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7 - SP-4/1(80% LIM FOS)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	19.8	8 - RP-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9 - PS-1/COAL C
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	A - PS-1/LIM NUC



5.4.5 Technologies using solar energy for the residential and commercial sector

The contribution of solar collectors varies little among scenarios, except for the RP-4 and SP-4/LIM FOS ones, where it logically has larger values. It is necessary to remark that the electric heat pump is more competitive in all scenarios, and its activity grows when the bounds or implementation are larger. Tables 14, 15 and 16 show the activity of solar collectors, electric heat pumps and gas heat pumps for all scenarios; the graph on page 111 shows the evolution of their activity.

SCENARIO COMPARISON REPORT FOR SPAIN

USEFUL ENERGY FROM SOLAR TECHNOLOGIES FOR RESIDENTIAL & COMMERCIAL SECTOR (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
0	4	7	11	14	18	18	18	18	PS-1
0	4	7	11	14	18	18	18	18	PS-1/OIL C
0	4	7	11	14	18	18	18	18	SP-1/($1.0/GJ)
0	4	7	11	14	18	18	18	18	SP-1
0	4	7	11	14	18	18	18	18	PS-4
0	4	7	11	14	18	18	18	18	SP-4/($1.0/GJ)
0	1	1	2	10	30	52	27	67	SP-4/LIM FOS
0	5	12	24	35	45	52	60	67	RP-4
0	4	7	11	14	18	18	18	18	PS-1/COAL C
0	4	7	11	14	18	18	18	18	PS-1/LIM NUC

TABLE 14

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: R2A, RTA

TECHNOLOGY: ELECTRIC HEAT PUMP (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
–	–	9	18	27	27	27	27	28	PS-1
–	–	9	18	27	27	27	27	28	PS-1/OIL C
–	–	9	18	27	27	27	27	28	SP-1/($1.0/GJ)
–	–	9	18	27	27	27	27	28	SP-1
–	1	11	21	32	34	38	42	41	PS-4
–	1	11	21	32	34	38	29	33	SP-4/($1.0/GJ)
–	0	0	0	0	0	0	42	46	SP-4/LIM FOS
–	5	21	31	32	34	65	65	65	RP-4
–	–	9	18	27	27	27	27	28	PS-1/COAL C
–	–	9	18	27	27	27	27	28	PS-1/LIM NUC

TABLE 15

SCENARIO COMPARISON REPORT FOR SPAIN

MARKAL CODE: R2B, RTB

TECHNOLOGY: GAS HEAT PUMP (PJ/YR)

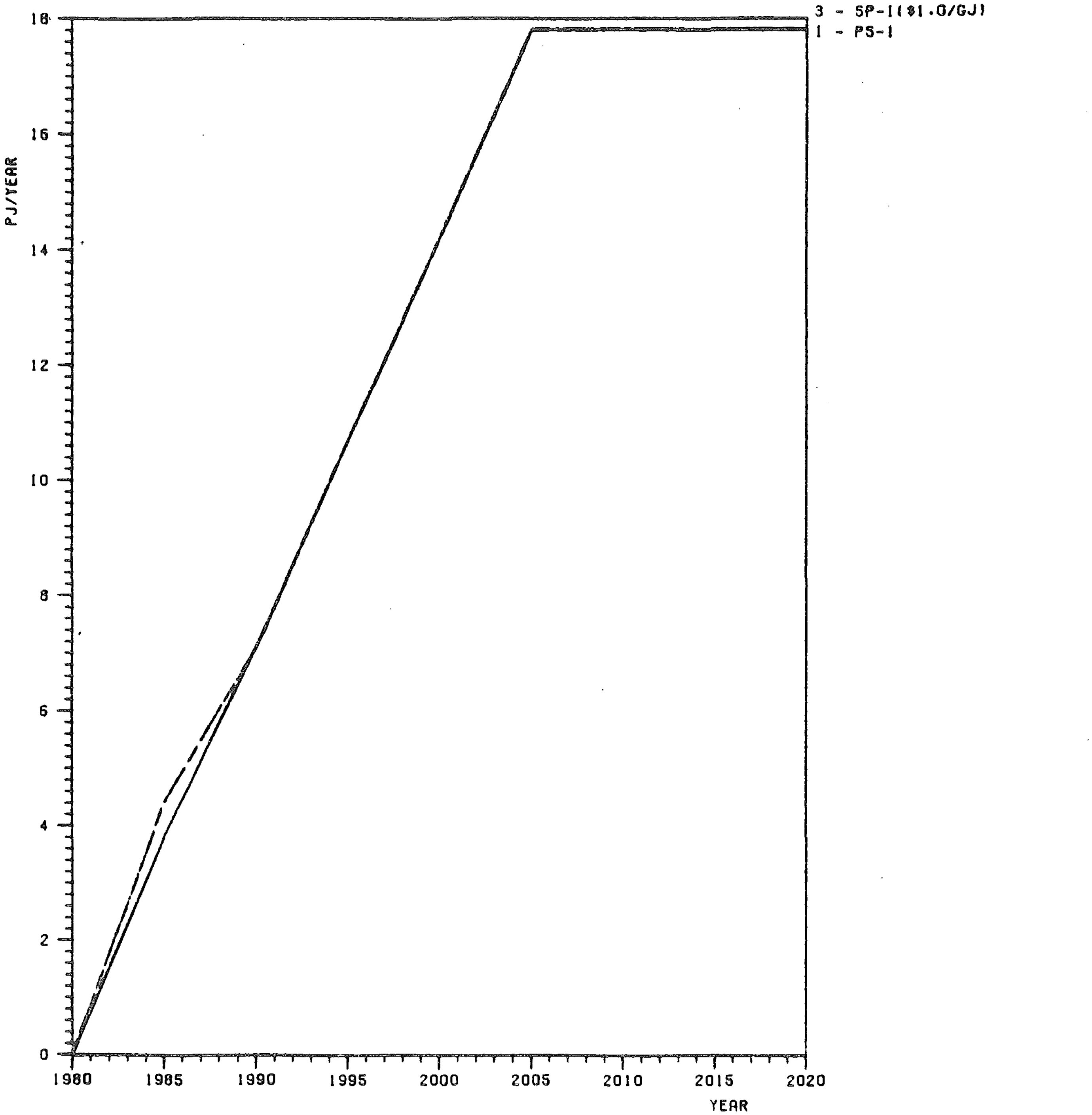
1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
–	–	1	5	8	11	10	7	4	PS-1
–	–	1	5	8	11	10	7	3	PS-1/OIL C
–	–	1	5	8	11	7	4	3	SP-1/($1.0/GJ)
–	–	1	5	8	11	7	4	3	SP-1
–	1	1	6	10	15	10	5	0	PS-4
–	1	1	1	0	0	0	0	0	SP-4/($1.0/GJ)
–	0	0	0	0	0	0	0	15	SP-4/LIM FOS
–	4	6	11	15	15	15	15	15	RP-4
–	–	1	5	8	11	11	11	11	PS-1/COAL C
–	–	1	5	8	11	11	11	11	PS-1/LIM NUC

TABLE 16

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 13: SOLAR FOR R & C: OUTPUT INCLUDING BACKUP (PJ/YEAR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	3.8	7.1	10.7	14.2	17.8	17.8	17.8	17.8	1 - PS-1
0.0	3.8	7.1	10.7	14.2	17.8	17.8	17.8	17.8	2 - PS-1/OIL C
0.0	4.4	7.1	10.7	14.2	17.8	17.8	17.8	17.8	3 - SP-1($1.0/GJ)
0.0	4.4	7.1	10.7	14.2	17.8	17.8	17.8	17.8	4 - SP-1
0.0	3.8	7.1	10.7	14.2	17.8	17.8	17.8	17.8	5 - PS-4
0.0	4.4	7.1	10.7	14.2	17.8	17.8	17.8	17.8	6 - SP-4($1.0/GJ)
0.0	0.7	1.4	2.1	10.4	29.5	51.6	27.2	67.2	7 - SP-4/1(80% LIM FOS)
0.0	4.9	12.4	23.6	34.9	44.9	52.3	59.8	67.2	8 - RP-4
0.0	3.8	7.1	10.7	14.2	17.8	17.8	17.8	17.8	9 - PS-1/COAL C
0.0	3.8	7.1	10.7	14.2	17.8	17.8	17.8	17.8	A - PS-1/LIM NUC



5.4.6 New renewable technologies for electricity production

Technologies:

E35 Wind power plant

E4B Decentralised solar photovoltaic plant

E34 Central solar thermal power plant

The group appears in all scenarios, although with small activities. Wind power plants are only competitive in two scenarios: the RP-4 (logically) and SP-4/LIM FOS. Both types of solar power plants show some activity only during the last two or three time periods. In the PS-1/LIM NUC scenario, their activity grows only slightly which means that these technologies contribute little to the substitution of nuclear energy for electricity production. Tables 17 and 18 show the corresponding activities for these technologies, and the graphs on pages 115 and 116 show their evolution.

5.4.7 Conventional nuclear power plants

Technology:

E21 Light water reactor

This technology shows high activity levels in all scenarios. The highest activity is that corresponding to the SP-4/LIM FOS scenario, because of the limited availability of fossil energy carriers. Table 19 shows the activities of this technology for all scenarios, and the graph on page 118 shows the evolution over the total time span.

5.4.8 New nuclear power plants

The following two technologies have been considered:

E25 High temperature reactor

E26 Fast breeder reactors

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: E4B

TECHNOLOGY: DECENTRALIZED SOLAR PHOTOVOLTAIC ELECTRIC (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
-	-	0	0	0	0	0	5	11	PS-1
-	-	0	0	0	0	0	5	11	PS-1/OIL C
-	-	0	0	0	0	0	0	6	SP-1/($1.0/GJ)
-	-	0	0	0	0	0	0	6	SP-1
-	-	0	0	0	0	0	0	9	PS-4
-	-	0	0	0	0	0	0	8	SP-4/$1.0/GJ)
-	-	0	0	2	6	10	16	21	SP-4/LIM FOS
-	-	1	2	4	8	11	16	21	RP-4
-	-	0	0	0	0	0	5	11	PS-1/COAL C
-	-	0	0	0	0	3	8	14	PS-1/LIM NUC

TABLE 17

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: E34

TECHNOLOGY: CENTRAL SOLAR THERMAL ELECTRIC (PJ/YR)

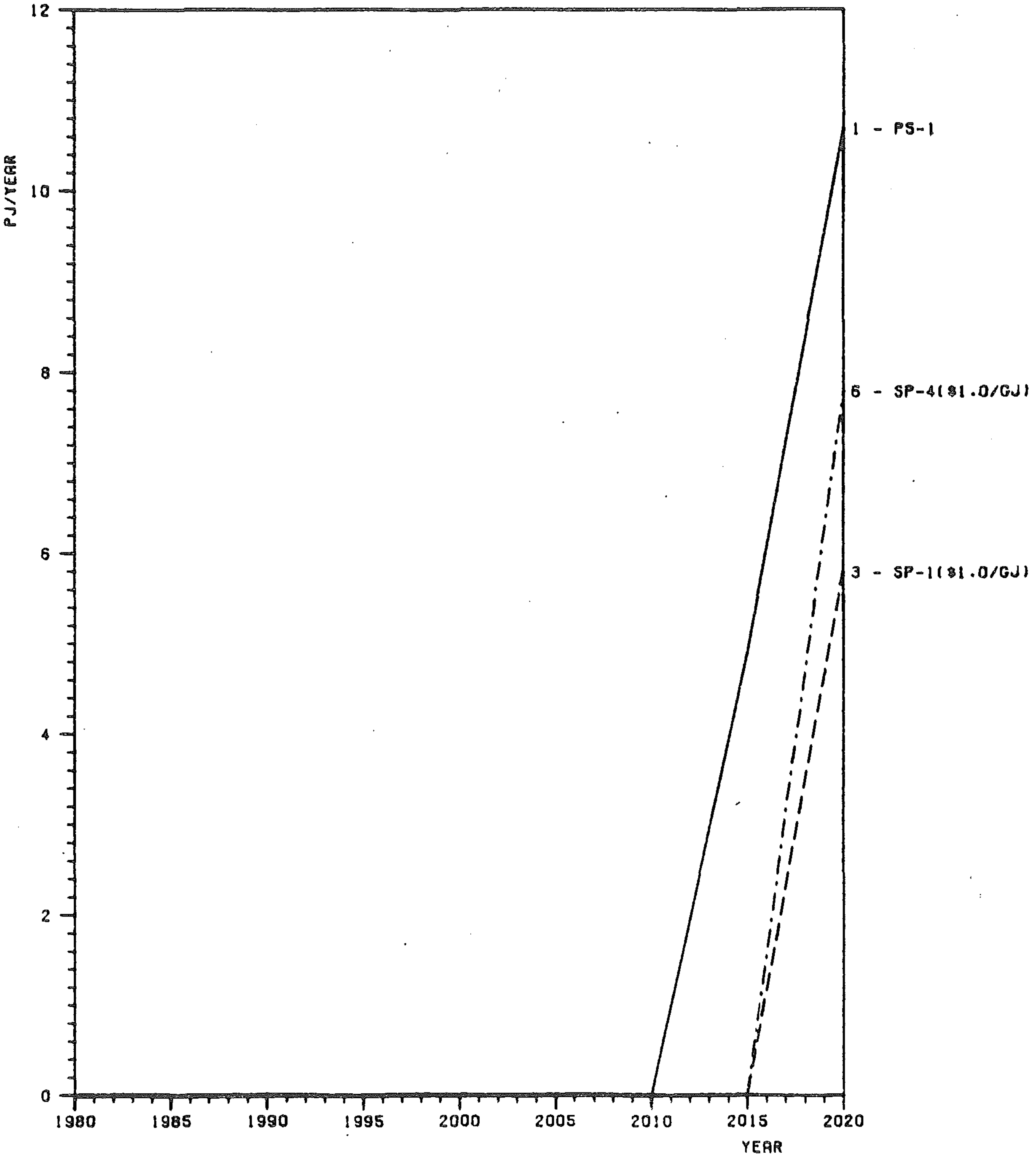
1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
-	-	-	0	0	0	0	0	6	PS-1
-	-	-	0	0	0	0	0	5	PS-1/OIL C
-	-	-	0	0	0	0	0	10	SP-1/($1.0/GJ)
-	-	-	0	0	0	0	0	16	SP-1
-	-	-	0	0	0	0	0	6	PS-4
-	-	-	0	0	0	0	0	20	SP-4/($1.0/GJ)
-	-	-	2	4	11	23	42	67	SP-4/LIM FOS
-	-	-	3	5	11	24	43	68	RP-4
-	-	-	0	0	0	0	0	0	PS-1/COAL C
-	-	-	0	0	0	0	0	16	PS-1/LIM NUC

TABLE 18

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 17: DECENTRALIZED PHOTOVOLTAIC.ELECTRIC PRODUCT (PJ/YR)

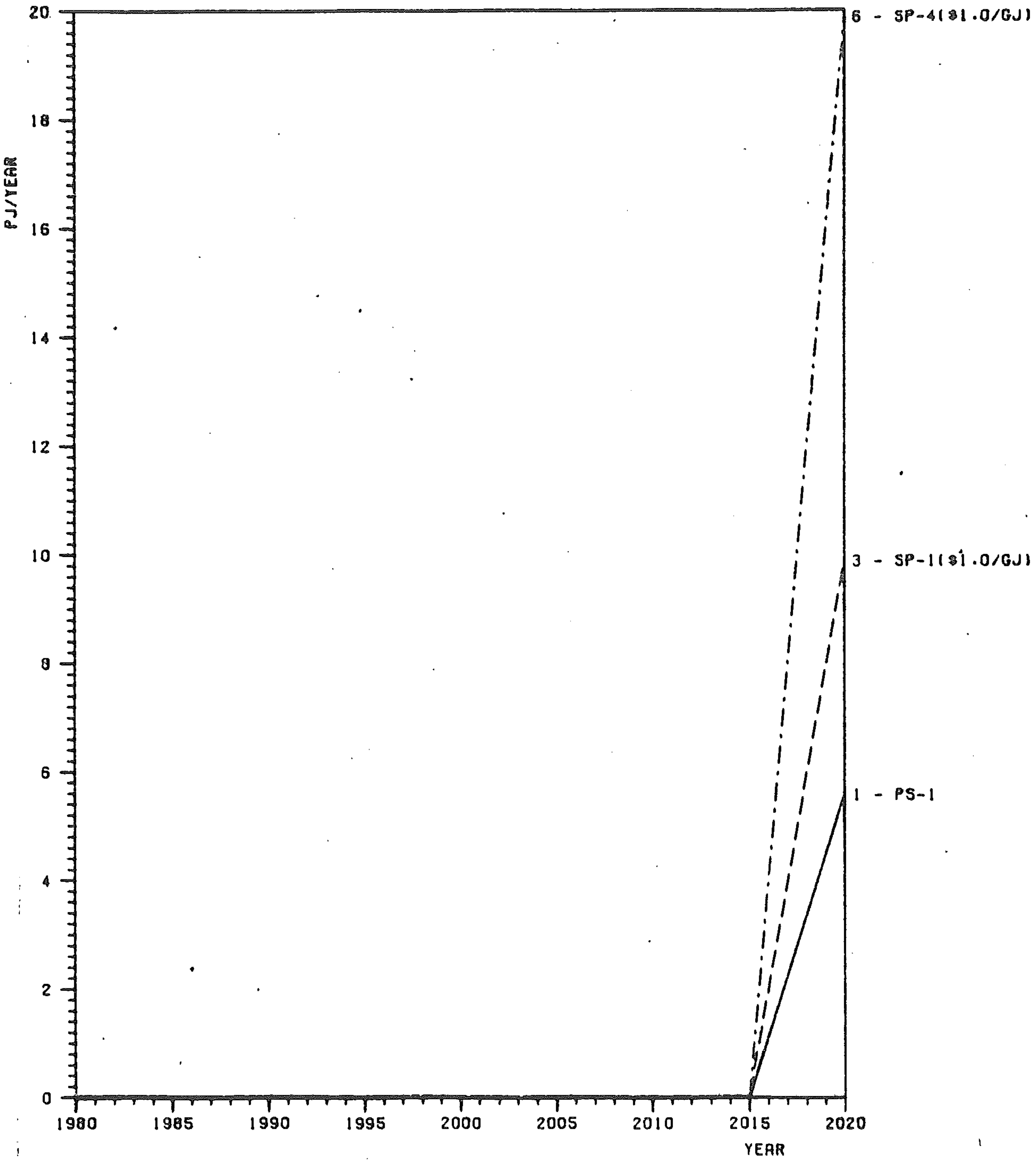
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	10.7	1 - PS-1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	10.7	2 - PS-1/OIL C
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	3 - SP-1($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	4 - SP-1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	9.0	5 - PS-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	6 - SP-4($1.0/GJ)
0.0	0.0	0.0	0.0	1.9	5.8	9.7	15.5	21.4	7 - SP-4/1(80% LIM FOS)
0.0	0.0	0.8	2.3	4.3	7.8	11.3	15.5	21.4	8 - RP-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	10.7	9 - PS-1/COAL C
0.0	0.0	0.0	0.0	0.0	0.0	2.9	7.8	13.6	A - PS-1/LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 18: CENTRALIZED SOLAR. ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	1 - PS-1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	2 - PS-1/OIL C
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	3 - SP-1($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4	4 - SP-1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	5 - PS-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.9	6 - SP-4($1.0/GJ)
0.0	0.0	0.0	1.9	4.4	10.7	23.3	42.2	67.4	7 - SP-4/1(80% LIM FOS)
0.0	0.0	0.0	2.5	5.0	11.3	23.9	42.9	68.1	8 - RP-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9 - PS-1/COAL C
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4	A - PS-1/LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: E21

TECHNOLOGY: LIGHT WATER REACTOR (PJ/YR)

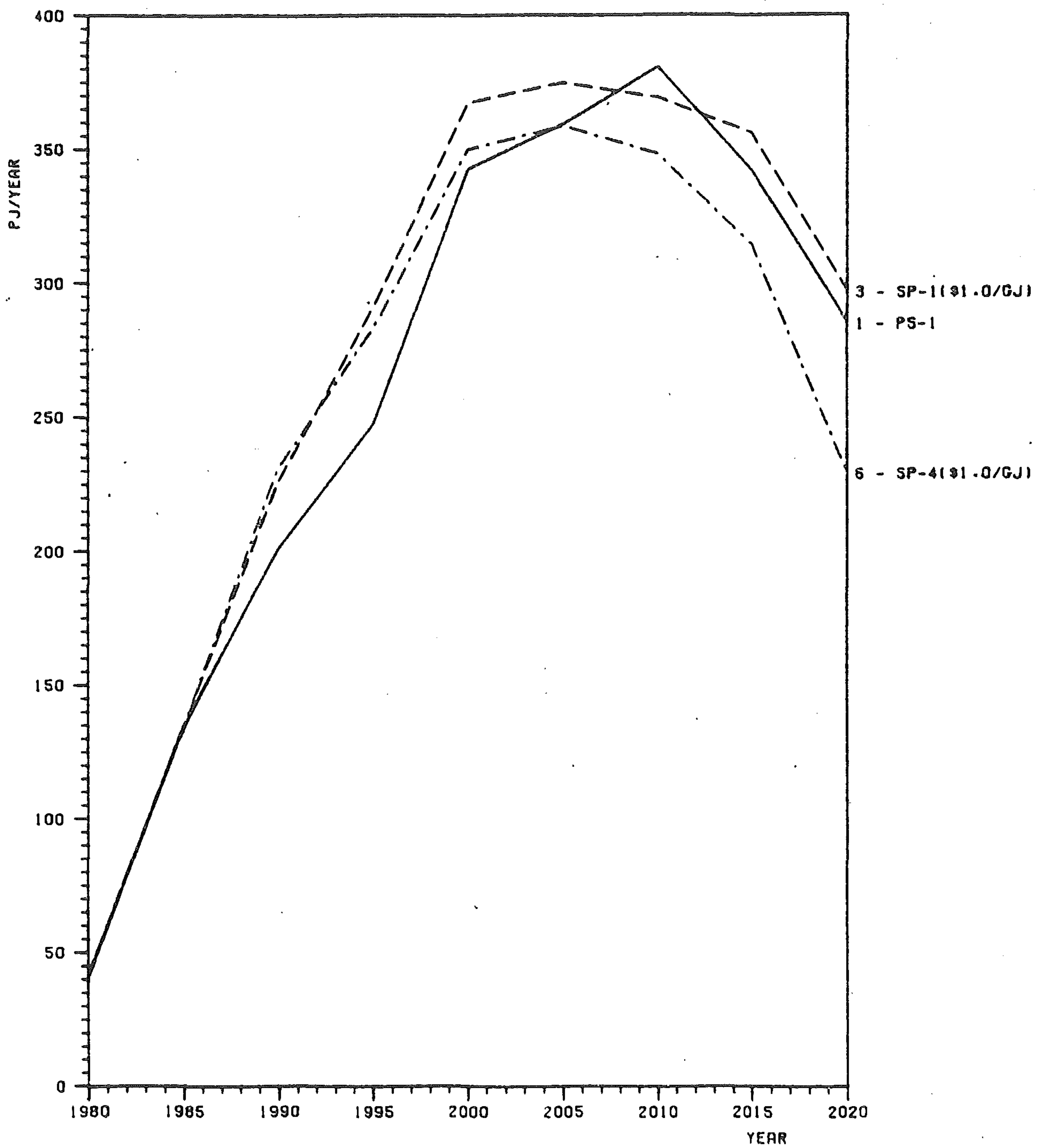
1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
41	134	201	247	343	359	381	342	286	PS-1
41	134	201	263	367	375	374	347	286	PS-1/OIL C
41	134	226	291	367	375	369	356	297	SP-1/($1.0/GJ)
41	168	239	291	370	381	383	380	329	SP-1
41	134	201	241	324	338	323	285	217	PS-4
41	134	231	283	350	359	348	314	230	SP-4/($1.0/GJ)
47	270	500	626	835	877	1092	940	959	SP-4/LIM FOS
41	134	201	224	305	305	277	202	135	RP-4
41	134	201	247	343	359	388	347	314	PS-1/COAL C
41	134	201	247	317	320	315	249	192	PS-1/LIM NUC

TABLE 19

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 20: LWR. ELECTRICITY PRODUCTION (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
41.3	134.3	201.4	247.2	342.7	359.3	380.6	342.0	285.5	1 - PS-1
41.3	134.3	201.4	262.7	367.3	374.8	374.2	346.5	285.7	2 - PS-1/OIL C
41.3	134.3	226.3	290.5	367.3	374.8	369.2	355.9	297.3	3 - SP-1($1.0/GJ)
41.4	167.9	239.0	291.0	369.9	380.6	382.8	380.1	329.0	4 - SP-1
41.3	134.3	201.4	240.5	323.9	338.4	322.7	284.5	217.3	5 - PS-4
41.3	134.3	231.4	283.0	350.0	358.7	348.2	314.4	229.5	6 - SP-4($1.0/GJ)
46.9	269.8	500.2	625.9	834.5	876.5	1091.5	939.8	959.0	7 - SP-4/1(80% LIM FOS)
41.3	134.3	201.4	224.1	304.8	304.8	277.0	202.4	135.3	8 - RP-4
41.3	134.3	201.4	247.2	342.7	359.2	388.2	347.4	314.3	9 - PS-1/COAL C
41.3	134.3	201.4	247.4	316.5	320.3	314.5	249.3	191.8	A - PS-1/LIM NUC



Both technologies appear in all scenarios, except in PS-1/LIM NUC. As can be seen from Tables 20 and 21, they are very competitive. In all scenarios with acceleration level 1, the activities are the same. This also applies in all level 4 acceleration scenarios. This means that these technologies are always at the top of their implementation levels. The graphs on pages 122 and 123 show the evolution of the respective activities.

5.4.9 New transportation technologies

Technologies:

S04 Methanol for cars

T8V Hydrogen for cars

T8O Electric battery car

Hydrogen for road transport is not competitive and does not appear in any scenario, but methanol is quite competitive, as shown in Table 9. It appears at its highest implementation level in many scenarios, mainly after the year 2005. It does not appear either in SP-4/LIM FOS or in PS-1/COAL C, which means that, as previously indicated, its competitiveness disappears if imported coal prices are increased.

The electric battery car is the most competitive technology for substituting oil-derived liquid fuels for transport. Table 22 shows that it always appears at its highest implementation level.

The graphs on pages 125 and 126 show the evolution over the whole time span of the electric battery car and the methanol-powered car.

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: E25

TECHNOLOGY: HIGH TEMPERATURE REACTOR (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
–	–	–	–	11	33	55	100	166	PS-1
–	–	–	–	11	33	55	100	166	PS-1/OIL C
–	–	–	–	11	33	55	100	166	SP-1/($1.0/GJ)
–	–	–	–	11	33	55	100	166	SP-1
–	–	–	4	20	47	73	129	217	PS-4
–	–	–	4	20	47	73	129	217	SP-4/($1.0/GJ)
–	–	–	4	20	47	73	129	217	SP-4/LIM FOS
–	–	–	4	20	47	73	129	217	RP-4
–	–	–	–	11	33	55	100	166	PS-1/COAL C
–	–	–	–	0	0	0	0	0	PS-1/LIM NUC

TABLE 20

SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: E26

TECHNOLOGY: FAST BREEDER REACTOR (PJ/YR)

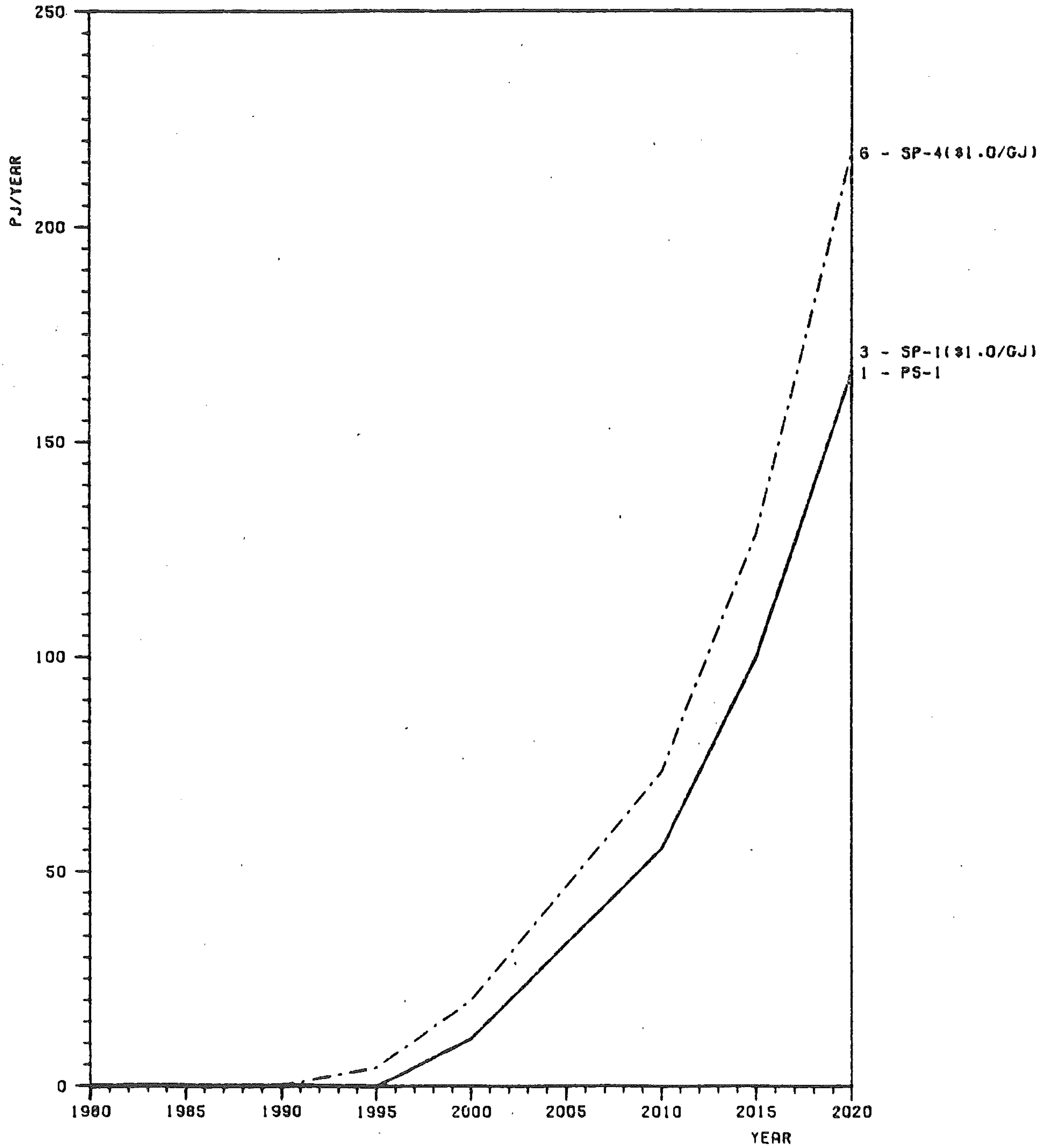
1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
-	-	-	-	11	33	60	93	137	PS-1
-	-	-	-	11	33	60	93	137	PS-1/OIL C
-	-	-	-	11	33	60	93	137	SP-1/($1.0/GJ)
-	-	-	-	11	33	60	93	137	SP-1
-	-	-	4	20	47	80	120	173	PS-4
-	-	-	4	20	47	80	120	173	SP-4/($1.0/GJ)
-	-	-	4	20	47	80	120	173	SP-4/LIM FOS
-	-	-	4	20	47	80	120	168	RP-4
-	-	-	-	11	33	60	93	137	PS-1/COAL C
-	-	-	-	0	0	0	0	0	PS-1/LIM NUC

TABLE 21

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 21: HTR. ELECTRICITY PRODUCTION (PJ/YR)

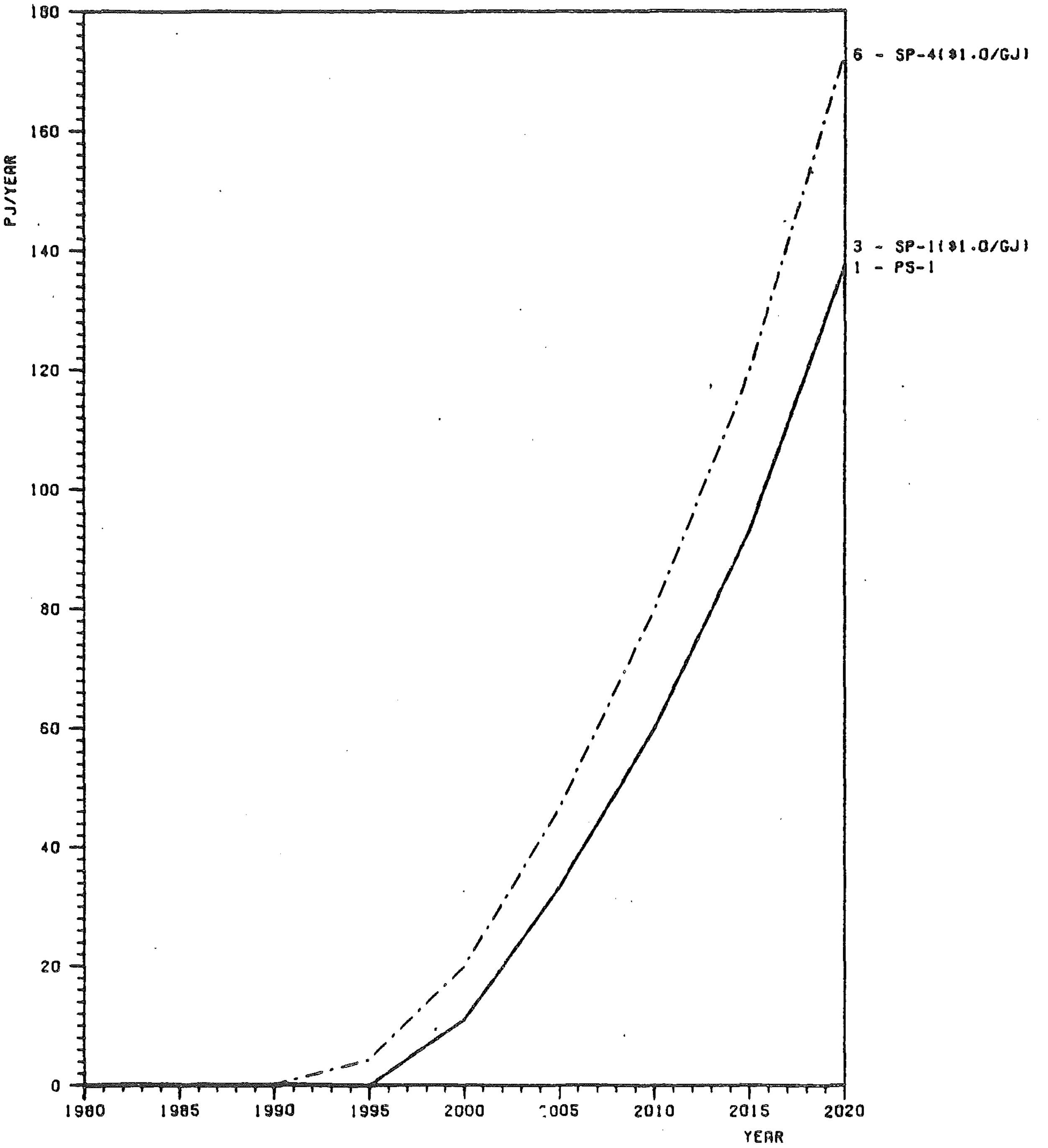
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	0.0	0.0	0.0	11.1	33.3	55.4	99.8	166.3	1 - PS-1
0.0	0.0	0.0	0.0	11.1	33.3	55.4	99.8	166.3	2 - PS-1/OIL C
0.0	0.0	0.0	0.0	11.1	33.3	55.4	99.8	166.3	3 - SP-1($1.0/GJ)
0.0	0.0	0.0	0.0	11.1	33.3	55.4	99.8	166.3	4 - SP-1
0.0	0.0	0.0	4.4	20.0	46.6	73.2	128.6	217.3	5 - PS-4
0.0	0.0	0.0	4.4	20.0	46.6	73.2	128.6	217.3	6 - SP-4($1.0/GJ)
0.0	0.0	0.0	4.4	20.0	46.6	73.2	128.6	217.3	7 - SP-4/1(80% LIM FOS)
0.0	0.0	0.0	4.4	20.0	46.6	73.2	128.6	217.3	8 - RP-4
0.0	0.0	0.0	0.0	11.1	33.3	55.4	99.8	166.3	9 - PS-1/COAL C
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	A - PS-1/LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 22: LIQUID METAL FAST BREEDER REACTOR.ELEC PROD (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	1	- PS-1
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	2	- PS-1/OIL C
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	3	- SP-1($1.0/GJ)
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	4	- SP-1
0.0	0.0	0.0	4.4	20.0	46.6	79.8	119.7	172.9	5	- PS-4
0.0	0.0	0.0	4.4	20.0	46.6	79.8	119.7	172.9	6	- SP-4($1.0/GJ)
0.0	0.0	0.0	4.4	20.0	46.6	79.8	119.7	172.9	7	- SP-4/1(80% LIM FOS)
0.0	0.0	0.0	4.4	20.0	46.6	79.8	119.7	168.0	8	- RP-4
0.0	0.0	0.0	0.0	11.1	33.3	59.9	93.1	137.4	9	- PS-1/COAL C
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	A	- PS-1/LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN MARKAL CODE: T80

TECHNOLOGY: ELECTRIC BATTERY CAR (PJ/YR)

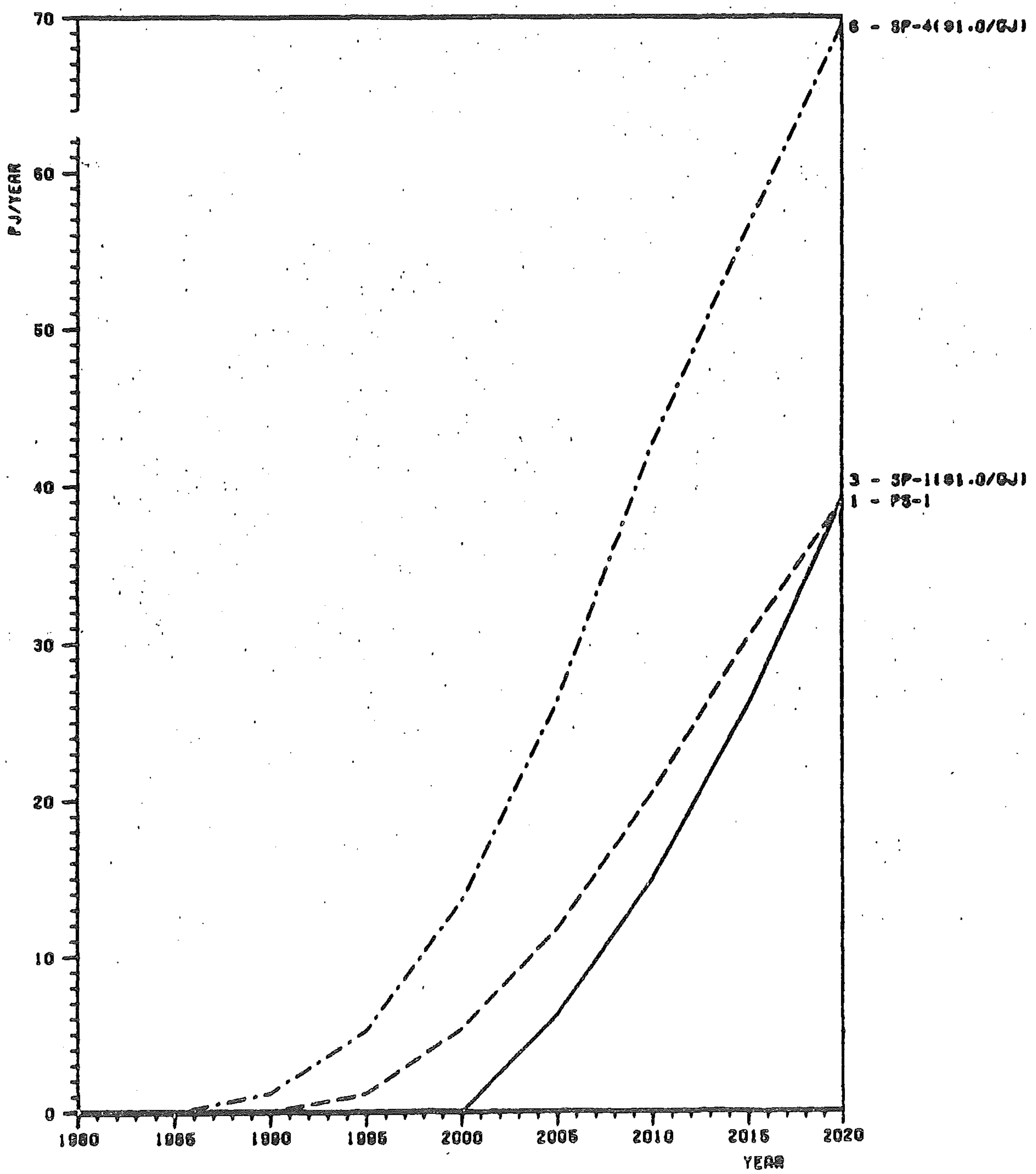
1980	1985	1990	1995	2000	2005	2010	2015	2020	SCENARIO
-	-	1	2	4	8	15	24	30	PS-1
-	-	1	2	4	8	15	24	30	PS-1/OIL C
-	-	1	2	4	8	15	24	30	SP-1/($1.0/GJ)
-	-	1	2	4	8	15	24	30	SP-1
-	1	5	10	15	20	30	40	39	PS-4
-	1	5	10	15	20	30	40	45	SP-4/($1.0/GJ)
-	1	5	10	15	20	30	40	45	SP-4/LIM FOS
-	1	5	10	15	20	30	40	45	RP-4
-	-	1	2	4	8	15	24	30	PS-1/COAL C
-	-	1	2	4	8	13	24	30	PS-1/LIM NUC

TABLE 22

SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 28: METHANOL FOR CARS (PJ/YR)

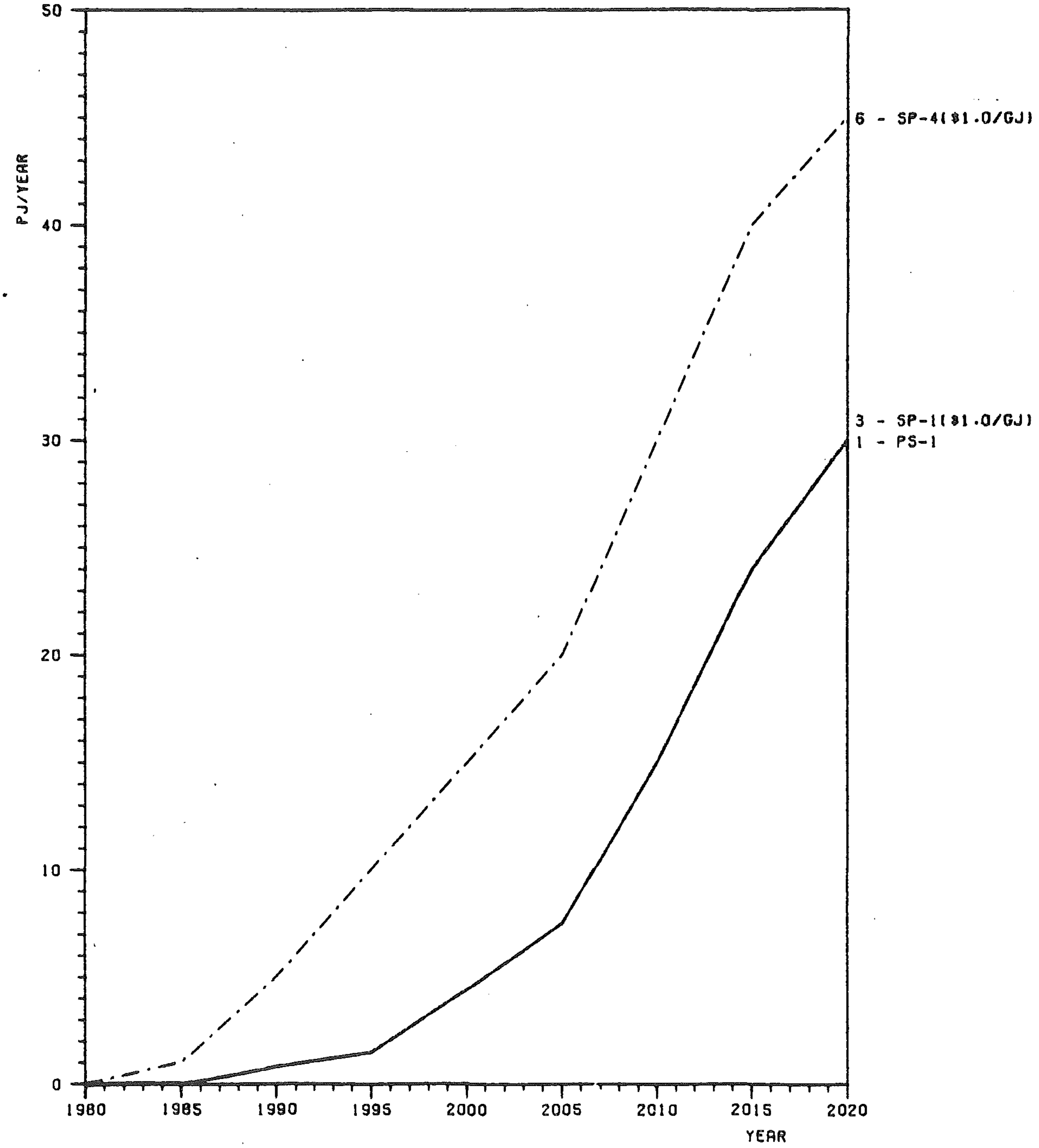
1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE	CODE
0.0	0.0	0.0	0.0	0.0	6.2	14.9	26.0	39.0	1	- PS-1
0.0	0.0	0.0	1.2	5.3	11.7	20.4	30.3	39.0	2	- PS-1/OIL C
0.0	0.0	0.0	1.2	5.3	11.7	20.4	30.3	39.0	3	- SP-1($1.0/GJ)
0.0	0.0	0.0	1.2	5.3	11.7	20.4	30.3	39.0	4	- SP-1
0.0	0.0	0.0	0.0	0.0	12.6	29.7	47.7	69.4	5	- PS-4
0.0	0.0	1.2	5.2	13.5	26.2	42.5	56.4	69.4	6	- SP-4($1.0/GJ)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7	- SP-4/1(80% LIM FOS)
0.0	0.0	0.0	0.0	0.0	12.5	29.7	47.7	69.4	8	- RP-4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9	- PS-1/COAL C
0.0	0.0	0.0	0.0	0.0	6.2	14.9	26.0	39.0	A	- PS-1/LIM NUC



SCENARIO COMPARISON REPORT FOR SPAIN DATE: 15/11/79

TABLE 30: ELECTRIC BATTERY CAR (PJ/YR)

1980	1985	1990	1995	2000	2005	2010	2015	2020	LINE CODE
0.0	0.0	0.8	1.5	4.4	7.5	15.0	24.0	30.0	1 - PS-1
0.0	0.0	0.8	1.5	4.4	7.5	15.0	24.0	30.0	2 - PS-1/OIL C
0.0	0.0	0.8	1.5	4.4	7.5	15.0	24.0	30.0	3 - SP-1($1.0/GJ)
0.0	0.0	0.8	1.5	4.4	7.5	15.0	24.0	30.0	4 - SP-1
0.0	1.0	5.0	10.0	15.0	20.0	30.0	40.0	39.2	5 - PS-4
0.0	1.0	5.0	10.0	15.0	20.0	30.0	40.0	45.0	6 - SP-4($1.0/GJ)
0.0	1.0	5.0	10.0	15.0	20.0	30.0	40.0	45.0	7 - SP-4/1(80% LIM FOS)
0.0	1.0	5.0	10.0	15.0	20.0	30.0	40.0	45.0	8 - RP-4
0.0	0.0	0.8	1.5	4.4	7.5	15.0	24.0	30.0	9 - PS-1/COAL C
0.0	0.0	0.8	1.5	4.4	7.5	13.1	24.0	30.0	A - PS-1/LIM NUC



6. ANALYSIS OF THE RESULTS

6.1 General Comments

The trade-off curve (Figure 10) shows the relationship between the total discounted energy system cost and the total amount of imported oil during the considered time span. This curve indicates that there is a low elasticity between the items: the total imported oil reduction (difference between the base case (PS-1) and the extreme case (SP-1) with the highest oil savings) is approximately 6% (1) and the difference between the respective system costs is smaller (approximately 1%).

Logically there is a larger saving on imported oil in the accelerated scenarios because of their higher new technology implementation levels; for instance, the SP-4/1.0 scenario achieves a reduction of more than 9% on imported oil. This means that it is possible to reduce the total amount of imported oil at relatively low cost by accelerating the implementation of new technologies. Of course it would be necessary to spend large sums of money on research and development of these new technologies and these funds are not included in the investment costs used by the model. It is therefore necessary to take into account the economic difficulties that this research and development would present for some IEA countries.

Another important item is the very high sensitivity of the Spanish energy system to restrictions in fossil fuel use. The greatest possible reduction of fossil fuel use is only 20%. With higher reductions, infeasible solutions are obtained because of the impossibility of satisfying the energy demand for some sub-sectors. Furthermore, the case of highest possible fossil fuel substitution implies a high total system cost increment (20%), and a larger total amount of imported oil (oil is more attractive for the system because it is more efficient in its use).

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(1) Unless otherwise noted, all percentages are referred to the corresponding value of the PS-1 scenario.

For the scenarios with limited nuclear energy availability (e.g. PS-1/LIM NUC scenario), the total system cost is higher than that for the base case in those periods during which the model would otherwise have installed nuclear plants at a level approximately 2% higher. In all such scenarios, the total amount of imported oil is nearly the same as for the base case, because nuclear energy competes mainly with coal, and a nuclear energy reduction implies an equivalent increment in coal use.

Another important remark is the key role played by the price of imported coal in the structure of the Spanish primary energy system, because of the high dependence on imports for the system. The PS-1/COAL C scenario (as explained above, in this scenario the annual growth rate in the price of imported hard coal is 3% instead of 2% as in the base case) shows a significant reduction in the hard coal imports. Some coal liquefaction technologies disappear, for example, methanol production for road transport. The scenario cost is 1.3% higher than for the base case.

The highest implementation level for technologies using renewable energy sources produces small reductions in imported oil (0.2%) with a larger system cost increment (1.3%). This is logical because such technologies produce electricity, and oil is normally not used for electricity production after the first two or three time periods. In fact, the total amount of renewable energy used is nearly the same for all scenarios, except for the RP-4 scenario as might be expected and for the SP-4/LIM FOS one. The latter is an extreme case because it contemplates an extreme reduction in fossil fuel use, and therefore the model utilises a large amount of renewable energy to substitute for fossil fuels.

Coal gasification technologies using high temperature reactors (HTR) have a smaller sensitivity to imported coal prices than those not using nuclear energy, but they logically have a very high sensitivity to restrictions of nuclear energy use.

6.2 Comparison between the SP-4/1.0 and PS-1 Scenarios

1) The total primary energy consumption is larger in SP-4/1.0 because oil is substituted by coal, although the differences are small, approximately 2%, depending on the time period. However, the total amount of imported oil decreases 9.1% after 1985, and the annual decrease reaches 15% during some time periods. The total amount of imported hard coal increases 25% over the base case, and the annual difference reaches 33% for some time periods. As for nuclear energy consumption, it shows some variation between the years 1990 and 2020 (in 2020 the nuclear energy consumption is again the same for both scenarios). It is 10% higher in the year 2000 for the SP-4/1.0 scenario. Renewable energy consumption is nearly the same for both scenarios.

   Imported natural gas disappears during the fifth time period (centred in the year 2000), five years earlier than for the base case, but the total amount of imported natural gas is approximately the same for both scenarios.

   Structural changes in primary energy consumption can be seen in Figure 11. The most important consideration suggested by the graphs is that the percentage of coal increases, covering the decreases in oil and nuclear energy, although the general structure is nearly the same for both scenarios.

2) The final energy also shows some structural changes (Figure 12); electricity production grows approximately 1% for all periods after 1990 and gaseous fuel use increases approximately 1% after 1985. Coal and liquid fuel use decrease between 1% and 1.5% after 1990, and renewable energy does not change.

3) The industrial sector shows the same structural changes observed in the final energy structure: coal consumption decreases 3% during the last time period (2020) and gas decreases 14%. The electricity consumption remains nearly the same.

FIGURE 11 : STRUCTURAL EVOLUTION OF PRIMARY ENERGY CONSUMPTION

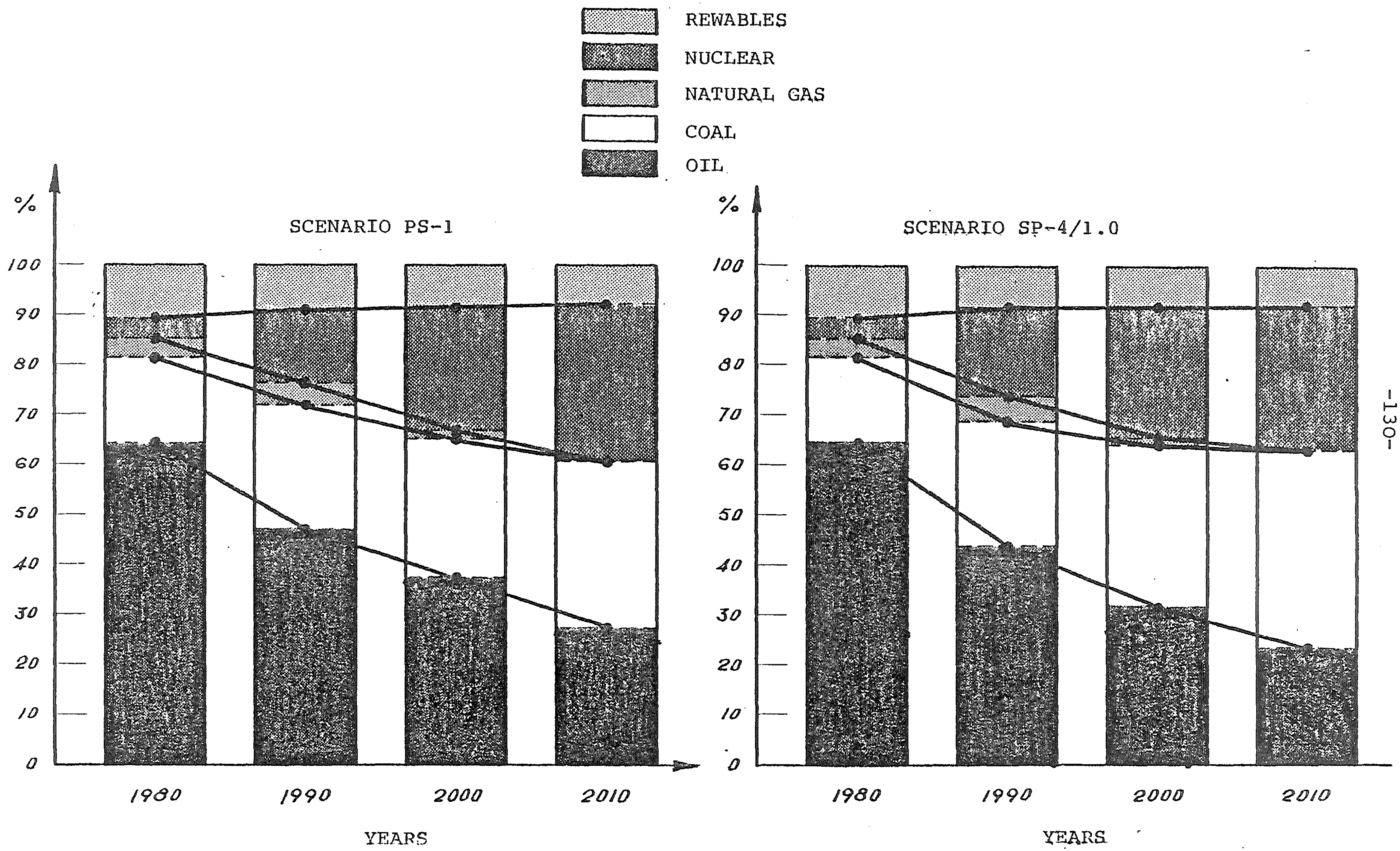
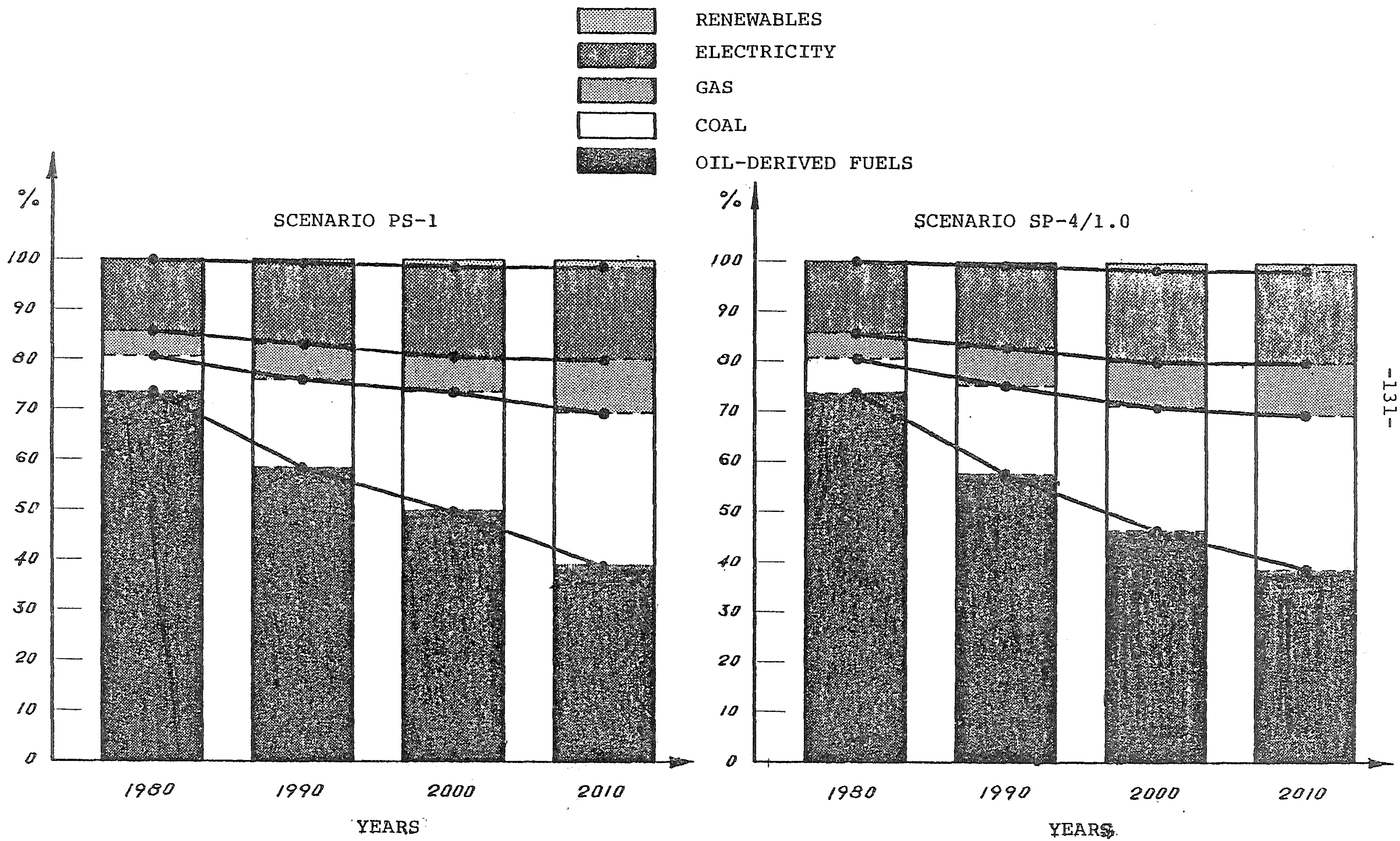


FIGURE 12 : STRUCTURAL EVOLUTION OF FINAL ENERGY CONSUMPTION



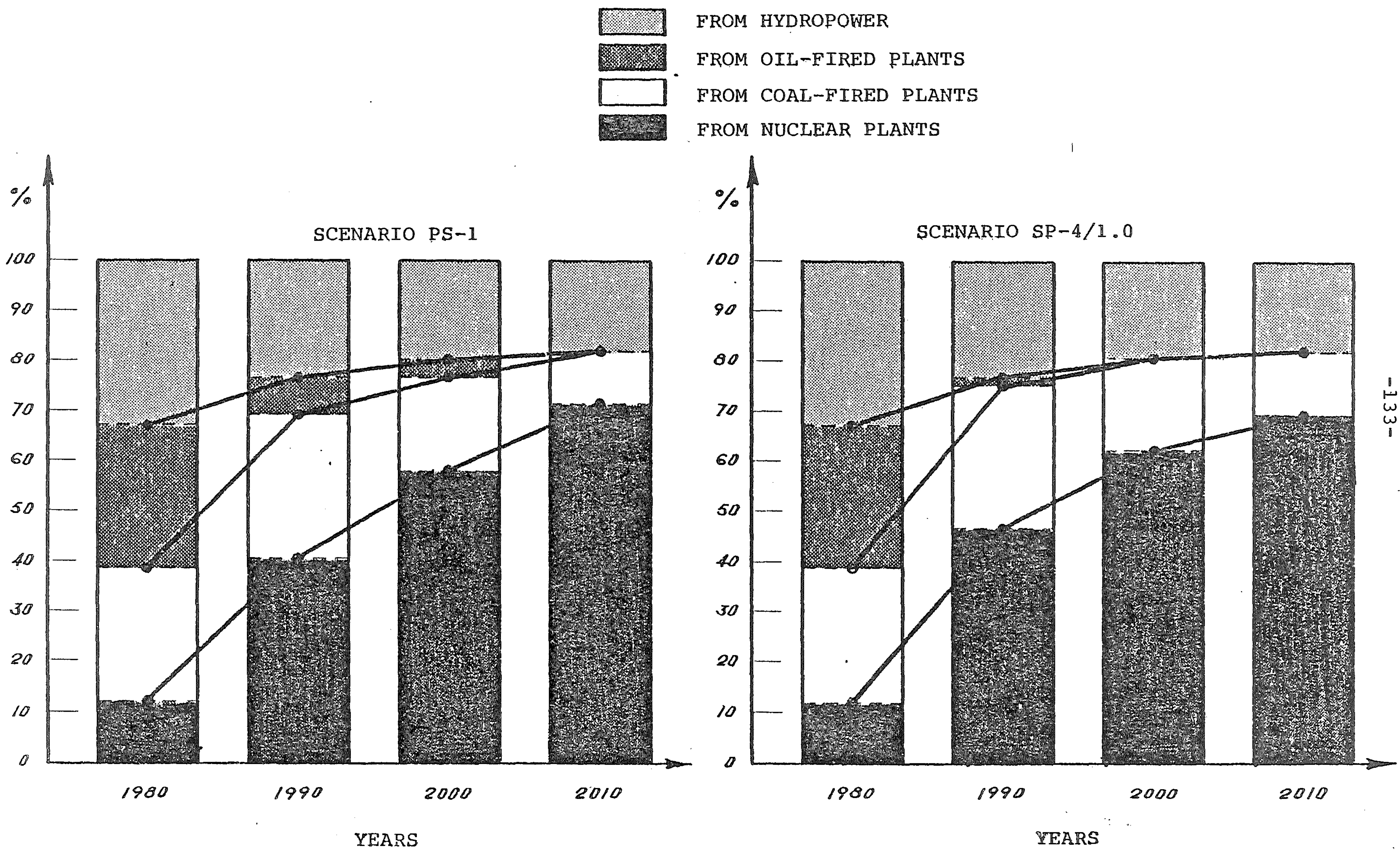
4) The residential and commercial sector shows some small changes; electric heat pump use increases by approximately 22% and the gas heat pumps disappear. Gas use also decreases but no more than 2.5%.

5) As for the transportation sector, the methanol use increases. It appears during the third time period (three periods earlier than for the base case), and the total increase is 125 PJ (4.3 x 10^t TCE). These increases are balanced by the corresponding decreases for DSL and gasoline.

6) Electricity production grows by approximately 1%. Figure 13 shows the structural changes. For intermediate time periods the oil consumption decreases and is substituted by nuclear energy. The percentage of hydroelectric energy use decreases continuously for both scenarios.

7) Synthetic fuel production from coal shows a large increase and a new process appears: Fischer-Tropsch, which did not appear for the base case. The total output from these technologies during the third time period, 1995, is multiplied by approximately 2.5, with respect to the base case. Afterwards, the growth rates are smaller, and for the last time period (2020) the rate is only 25% higher. The Lurgi brown coal gasification process almost disappears and only produces 1 PJ (0.03 x 10^6 TCE) during the sixth time period (2005). This reduction is balanced by the nuclear brown coal hydrogasification.

FIGURE 13: EVOLUTION OF PRIMARY ENERGY CONSUMPTION FOR ELECTRICITY PRODUCTION



6.3 Comparison between the Base Case (PS-1) and the PS-1 OIL C Scenario

The oil contribution to primary energy is smaller in the PS-1 OIL C scenario after the year 1990. The coal contribution grows and partially covers the decrease of oil contribution; the increase reaches 10% in the year 2000. The nuclear energy contribution has a similar evolution reaching an increase of 7% in the year 2000. The renewable energy contribution changes very little. Oil imports logically decrease because of the higher oil prices. The total amount of imported oil is 3% smaller. This decrease is covered by larger amounts of imported coal ($\cong$ 7%) and natural gas.

The structure of final energy consumption shows a smaller contribution from liquid fuels between 1990 and 2005 (approximately 5% smaller). This decrease is completely covered by gaseous fuels. For the remaining years, the values for both scenarios are approximately the same. As for the demand sectors, the following considerations can be made:

- The industrial sector shows the same substitution of liquid fuels by gaseous ones already observed in final energy consumption.

- The residential and commercial sector does not show changes.

- The transportation sector shows an increase in methanol use, which appears ten years earlier than in the base case (in 1995). The total increase is 21 PJ (approximately 0.7×10^6 TCE).

The electricity production remains nearly the same. It is quite logical because oil is not used for electricity production after the first 10 or 15 years. The structure of electricity production shows that only approximately 65 PJ (2.2×10^6 TCE) of electricity which was produced by the oil power plants in the base case is now produced by LWR in the PS-1/OIL C scenario.

Synthetic fuel production from coal grows between the years 1995 and 2020 and the difference reaches 10% in the year 2005. The values for the year 2020 are again the same. The most relevant increase is the one for hard coal hydrogasification. Methanol production also grows (approximately 25%, although this percentage means, in real terms, only 30 PJ (1.1×10^6 TCE).

6.4 Comparison between the Base Case and the PS-1 COAL C Scenario

The total primary energy consumption slightly decreases (coal is being substituted by oil, which, as indicated above, has higher efficiencies); the difference is not larger than 1.5%. The contributions of natural gas and renewable energy remain practically unchanged. The nuclear energy contribution grows after 2000, reaching an increase of 3% in the year 2020; the total increase during the total time span is approximately 2%. The oil contribution also increases after 2000 and, in 2020, is 12% higher. Logically the coal contribution decreases after 2000, and in 2020 is roughly 20% lower. This indicates that the Spanish energy system has a very large sensitivity to coal prices and therefore the assumptions made about these prices strongly influence the results. The total amount of imported oil grows approximately 3.2% and that of imported coal logically decreases (13%). The decrease reaches 30% for some years.

The final energy consumption shows an increase in liquid fuel contribution between the years 1995 and 2010, although the difference does not reach 2%. This increase is balanced by gaseous fuel, and the same substitution can be observed in the structure of the industrial sector. In the residential and commercial sector the gas heat pump contribution is 7 PJ larger, and the direct contribution of gas is 7 PJ smaller, because synthetic gas is more expensive in the PS-1/COAL C scenario. In the transportation sector, the methanol use disappears, because with the higher coal prices it is not competitive.

The electricity production remains nearly the same. The hard coal combined cycle disppaears and it is substituted by LWR.

The production of synthetic fuels from coal shows the disappearance of hydrogenation and methanol production. Nuclear gasification technologies grow approximately 20%, but in spite of this the total amount of synthetic fuel decreases by approximately 18% after the year 2000.

6.5 Comparison between the Base Case and the PS-1 LIM NUC Scenario

The primary energy consumption decreases although the differences are not larger than 2%. The contribution of solid fuels after 1990 is logically larger; the difference grows continuously and reaches 60% in the year 2020. The oil contribution is nearly the same, with some fluctuations, which do not reach 2%. It is possible to observe that the limitation on nuclear energy use causes an increase in total system cost. The difference grows continuously reaching 10% in 2020. The nuclear energy contribution decreases after 1990, and becomes less than 33% in 2020. The contribution of renewable energy is practically the same. These facts mean that nuclear energy is substituted mainly by coal and to a lesser extent by natural gas. Oil imports show a small increase and natural gas imports grow strongly after 1990. There are gas imports after 2005 (this does not occur in the remaining nine scenarios). The total amount of imported natural gas is 85 PJ (28.7 x 10^6 TCE) larger than that for the base case. Coal imports are also much higher after 1990, becoming almost 100% more in the year 2020.

As for the final energy consumption, the coal contribution hardly changes. The liquid fuel contribution increases between 1995 and 2010, although the differences are smaller than 1.5%. This increase is balanced by gaseous fuel use. The differences are small in real terms. The industrial sector shows the same substitution of liquid fuel by gaseous ones. In the residential and commercial sector the gas heat pump use increases 7 PJ ($\simeq$ 0.3 x 10^6 TCE). This is balanced by a decrease in the use of gas burners. The transportation sector hardly changes.

As for the structure of electricity production, it can be observed that the nuclear energy contribution decreases (logically). The HTR and LMFBR do not appear and the activity of the LWR decreases after 1995, becoming only 50% of that in the base case in 2020. These decreases are covered by coal, with conventional coal-fired power plants covering approximately 70% of the decrease of nuclear, hard coal combined cycle (20%) and in-situ coal gasification and solar covering the remaining 10%.

Coal-derived liquid fuel production shows some important changes; all technologies combined with the HTR logically disappear, and a new one appears; hard coal medium BTU gasification. Brown coal Lurgi gasification grows, and its activity becomes seven times that of the base case, and also appears during the last ten years which did not occur in the base case. In spite of this, the total amount of synthetic fuel is only 60% of that for the base case.

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